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AEROMEDICAL REVIEW

CENTRAL DENTAL EVACUATION SYSTEMS

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May 1982

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USAF SCHOOL OF AEROSPACE MEDICINE
Aerospace Medical Division (AFSC)
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This technical report has been reviewed and is approved for publication.

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UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Aeromedical Review 3-82	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CENTRAL DENTAL EVACUATION SYSTEMS		5. TYPE OF REPORT & PERIOD COVERED Final Report August 1980 - July 1981
		6. PERFORMING ORG. REPORT NUMBER SAM-TR-82-12
7. AUTHOR(s) Joseph M. Powell, Colonel, USAF, DC John M. Young, Colonel, USAF, DC		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS USAF School of Aerospace Medicine (NGD) Aerospace Medical Division (AFSC) Brooks Air Force Base, Texas 78235		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 87714F DSB38900
11. CONTROLLING OFFICE NAME AND ADDRESS USAF School of Aerospace Medicine (NGD) Aerospace Medical Division (AFSC) Brooks Air Force Base, Texas 78235		12. REPORT DATE May 1982
		13. NUMBER OF PAGES 53
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Central evacuation systems, dental
Oral evacuation systems, central, dental
Surgical suction, dental, central
Dust-collection systems, central, dental

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Four central evacuation systems are detailed. To enhance the technical aspects, a complete systems component description is prefaced by an introduction to vacuum theory. Specifications, design guidance, and acceptance testing are included. The information contained is intended for use by base dental staff, health facilities personnel, architects, engineers, and contractors.

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PREFACE

The information provided in this report is applicable both to exigent and specified-location minor construction projects and to major military construction projects. The purpose of this report is to

a. provide dental staff personnel with a more comprehensive knowledge of the design and function of central dental evacuation systems;

b. establish working details for the most efficient and cost-effective dental evacuation systems consistent with present and projected military dental practice requirements;

c. provide clear, concise equipment configuration and performance requirements as guidance to health facilities offices so that they may closely supervise planning for central dental evacuation systems; and

d. provide procurement, installation, and performance criteria to contractors to assure delivery of equipment consistent with quality design, longevity, and clinical performance.

Four central dental evacuation systems (identified by AFM 88-50, Criteria for Design and Construction of Air Force Health Facilities) are discussed. Part I of this report includes the theory of vacuum operation, the details of the systems, their component parts, and their function. Part II presents specifications, design guidance, acceptance testing, and utilities requirements. Sufficient detail is provided to permit identification of well-designed systems and components as well as of those that do not meet U.S. Air Force requirements. A glossary of definitions and abbreviations is included at the end of the report to enhance comprehension of the systems' descriptions, specifications, and design guidance.

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PART I

INTRODUCTION

Vacuum Theory

The performance of any vacuum generating system is based on two essential factors: (1) volume of airflow (CFM) and (2) vacuum pressure (inHg) maintained in the system. In a functioning vacuum system, air is the transporting medium for effluent and debris (rate of airflow determines volume transported), while vacuum pressure provides the energy for transportation. These two essential factors operate in inverse proportion as demonstrated in Figure 1:

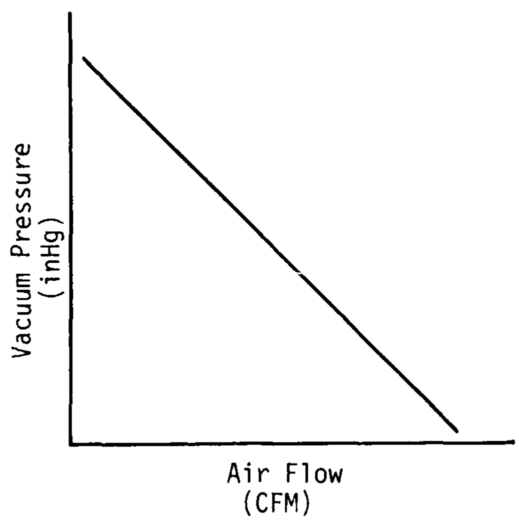

Figure 1. Vacuum system performance.

When vacuum pressure is at a peak, airflow is minimal, and vice versa. With few exceptions, a high level of either one of these factors does not provide a practical vacuum system. A system with very high vacuum pressure but little or no airflow has energy to slowly move liquids and solids but lacks sufficient volume to efficiently collect airborne debris. In addition, low airflow cannot provide sufficient capture velocity to seize particulates thrown from high-speed cutting operations. At the other extreme, a system with a high airflow but little vacuum pressure can move very lightweight air-suspended material but lacks the energy required to collect liquids and solid particles with moderate mass.

Some vacuum systems are designed to operate in a performance range between the extreme ends of the graph lines of Figure 1. The performance requirements of this type of system are usually not critical and are generally the result of a compromise between optimal performance and factors such as cost, weight, and portability. An example is the household vacuum cleaner. Hose attachments used on these units have varied intake sizes which affect both airflow and vacuum pressure. Consequently these devices seldom operate at their potential optimum level of performance. Additional engineering necessary to fix the levels of airflow and vacuum pressure are not practical in these portable systems.

Conversely, the performance requirements of a dental evacuation system are far more restrictive on design. These systems must be designed around specific vacuum pressure and airflow levels determined to be most effective in scavenging liquids, solids, and aerosols. The system design must be such that the preset levels of these essential factors are maintained regardless of the number of using dental treatment rooms (DTR), from one to full clinic capacity. To maintain these levels, the vacuum generator requires specialized accessories.

Vacuum Generators

In most commonly observed applications, a turbine is driven by the air, gas, or liquid medium passing through it and is coupled to some other device to perform work. A turbine can, when driven by an external mechanical force, be used as an exhaust or vacuum pump. In this type of application, the turbine is more appropriately termed a turboexhauster. This is perhaps the most efficient and reliable means available for moving large volumes of air under vacuum pressure. In addition, the internal design of the turboexhauster gives it the unique ability to build and sustain predetermined levels of vacuum pressure. These two features qualify this exhauster as the ideal vacuum generator for vacuum systems required to handle large volumes of air at low to medium vacuum pressure.

A turboexhauster is basically a multistage centrifugal pump with rotors, or impellers, mounted one behind the other on a common shaft. These are illustrated by the diagonally striated parts in Figure 2. The path of air through the turboexhauster is indicated by the heavy arrow lines. Air enters the front chamber (first stage) of the turboexhauster near the shaft center. From here air is picked up and given centrifugal (outward) acceleration by the first impeller. After leaving the axial tips of the impeller, the air undergoes a 180° change in direction and increases in acceleration. Fixed vanes located behind the impeller redirect the air back toward the shaft, to the base of the next impeller. During this inward return, air velocity is reduced as its kinetic energy (energy of motion) is converted to pressure energy. The increase in pressure energy causes a corresponding positive pressure increase at the pump outlet and a vacuum pressure increase at the inlet. The direction change and pressure increase are repeated through each stage of the turboexhauster. Consequently the vacuum pressure requirement for a specific system directly influences the number of stages needed in the turboexhauster. Impeller dimensions also influence performance. Generally, increasing impeller width provides greater capacity, or airflow, and increasing impeller diameter improves vacuum pressure.

The inherent characteristics of the turboexhauster make it ideal for the high airflow requirements of most dental evacuation systems. It is not, however, suitable for use in a system where high pressure is essential, such as a surgical vacuum. The number of stages and the impeller diameter for such a turboexhauster would be prohibitive.

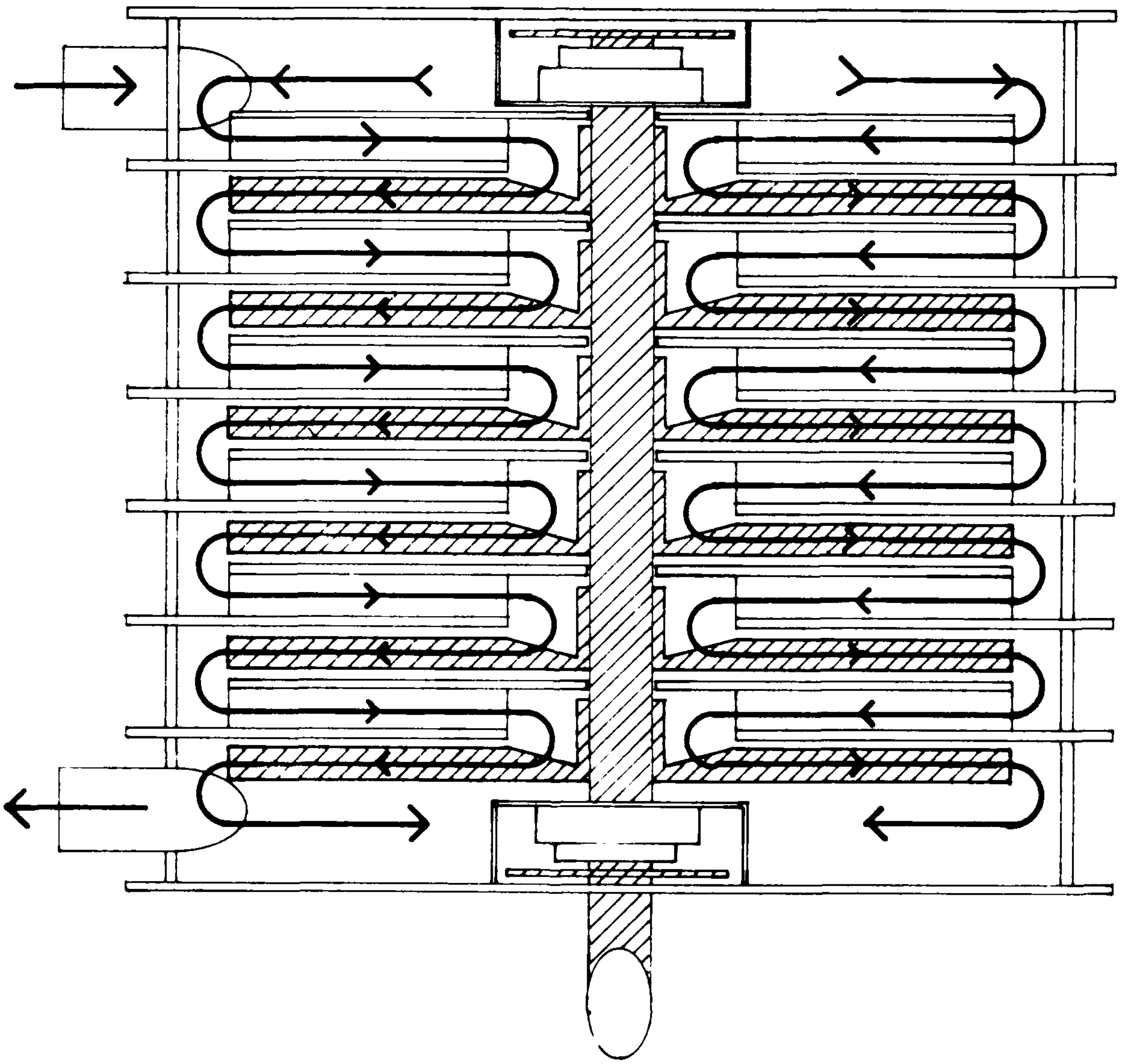

Figure 2. Turboexhauster (cross section).

The vacuum generator of choice for surgical evacuation is the water-ring, or water-injected, pump. A cross section of this device is illustrated in Figure 3. Like the turboexhauster, the only moving part is the shaft/rotor assembly. This pump may be a single- or two-stage unit. A quantity of water is maintained in the pump body and is formed in a ring configuration by the spinning rotor. The water ring (shown as the stippled area in Fig. 3) centers itself in the pump body. Note that the rotor and shaft are offset. This offset allows the water to serve as a liquid compressant as it partially, and then almost completely, fills each rotor chamber during each rotation. This pistonlike action charges and discharges air through the intake and exhaust ports respectively (located in the stationary center section) without the need for valves. Due to the limited capacity of the individual rotor chambers, this pump can move only small air volumes but can routinely maintain vacuum pressures of 25 inHg, which is approximately three times that of a turboexhauster of equivalent horsepower.

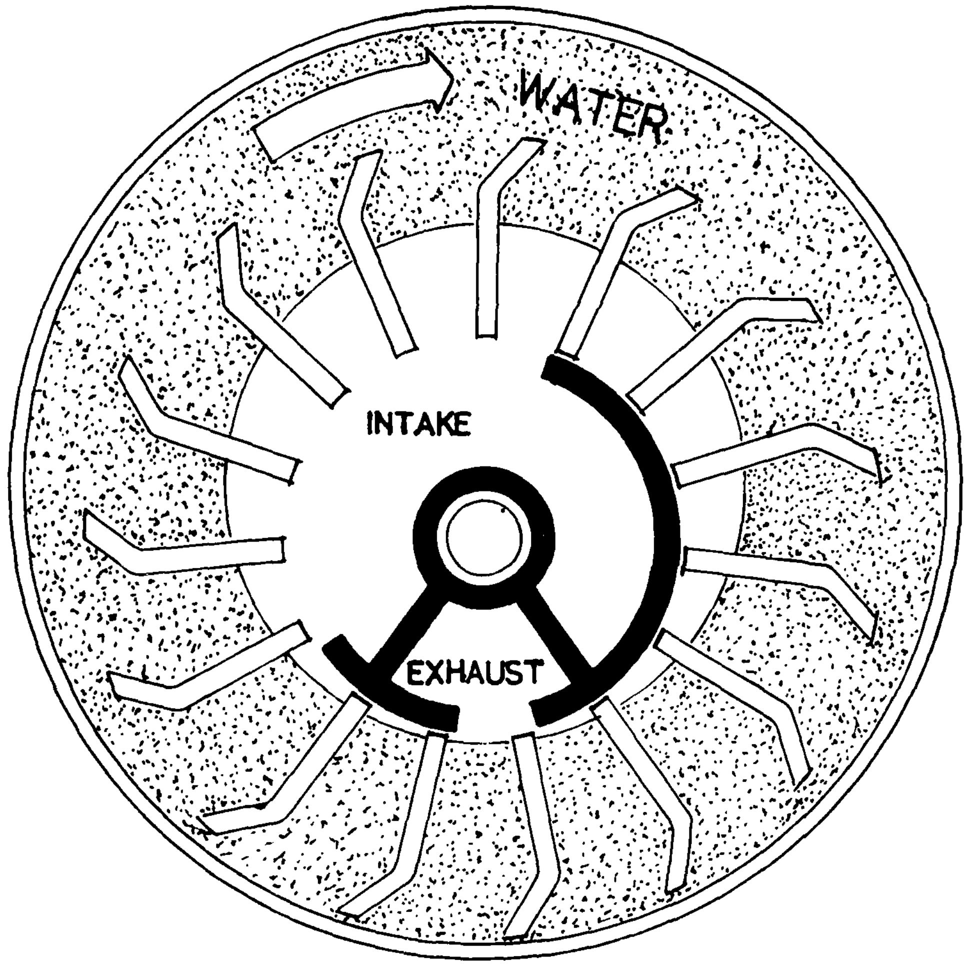

Figure 3. Water-ring pump (cross section).

CENTRAL EVACUATION SYSTEMS

Four types of central evacuation systems are used in modern dental facilities. Two are for oral use: the high-volume evacuation system (HVE), used throughout the dental clinic in all patient-treatment areas; and the high-vacuum evacuation system (HIVAC), used in specific disciplines of practice. The third central system is the high-volume evacuation system for dental laboratories (HVEL), or the central dust-collection system as it is perhaps more generally described in lay terms. The fourth system is the environmental-janitorial vacuum system (EJVS), with inlets throughout the facility for environmental-protection housekeeping and cleanup procedures.

Due to their role as essential ancillary equipment for direct mission support, the two oral evacuation systems are dual in nature to provide a 100% capacity backup system in the event of vacuum-generator failure. The HVEL, being less highly stressed and of less priority in mission support, is provided as a single vacuum-generator system. Each of the four systems is designed for a specific purpose and is therefore different in component makeup and performance. These systems must be discussed separately for a fuller understanding of their design and purpose.

High-Volume Oral Evacuation System (HVE) for Dental Treatment Rooms

This central system, as its name implies, is designed to provide high-capacity air movement and does so at moderate vacuum pressure. It is specifically designed to collect and remove aerosols of water, saliva, and grinding or cutting debris from the mouth of the patient, especially during use of the high-speed handpiece. Inlets to this system are required throughout the dental facility for all disciplines of patient treatment where coolant and irrigation liquids are introduced into the operating field. These inlets are all connected to a central collection point and function as a wet-type system, with both air and liquid carried through the central piping. Vacuum is provided by turboexhausters.

Operational Parameters

Essential factors of 15-CFM volume and 8-inHg vacuum pressure for this system were established through long-term clinical trial. The flow characteristics of blown air and exhausted air have a basic difference. The principle is illustrated in Figure 4. Air blown from an outlet of a given diameter retains its directional effect for some distance beyond the outlet or orifice face. The raw quantity of air being exhausted into a same-sized orifice is almost completely nondirectional; therefore, its range of influence is greatly reduced. In Figure 4, the air velocity at the face of each orifice is 3000 FPM. Blowing air retains 10% of its initial velocity for a distance equal to 30 times the orifice diameter. Exhausting air, on the other hand, retains 10% of its face velocity only 1 diameter from the orifice face. Actual values can be applied to find an approximate spray velocity for a hypothetical handpiece, using the following airflow equation:

$$V = \frac{Q}{A}$$

where: V = Velocity (FPM)
Q = Air volume delivered (CFM)
A = Orifice area (ft^2)

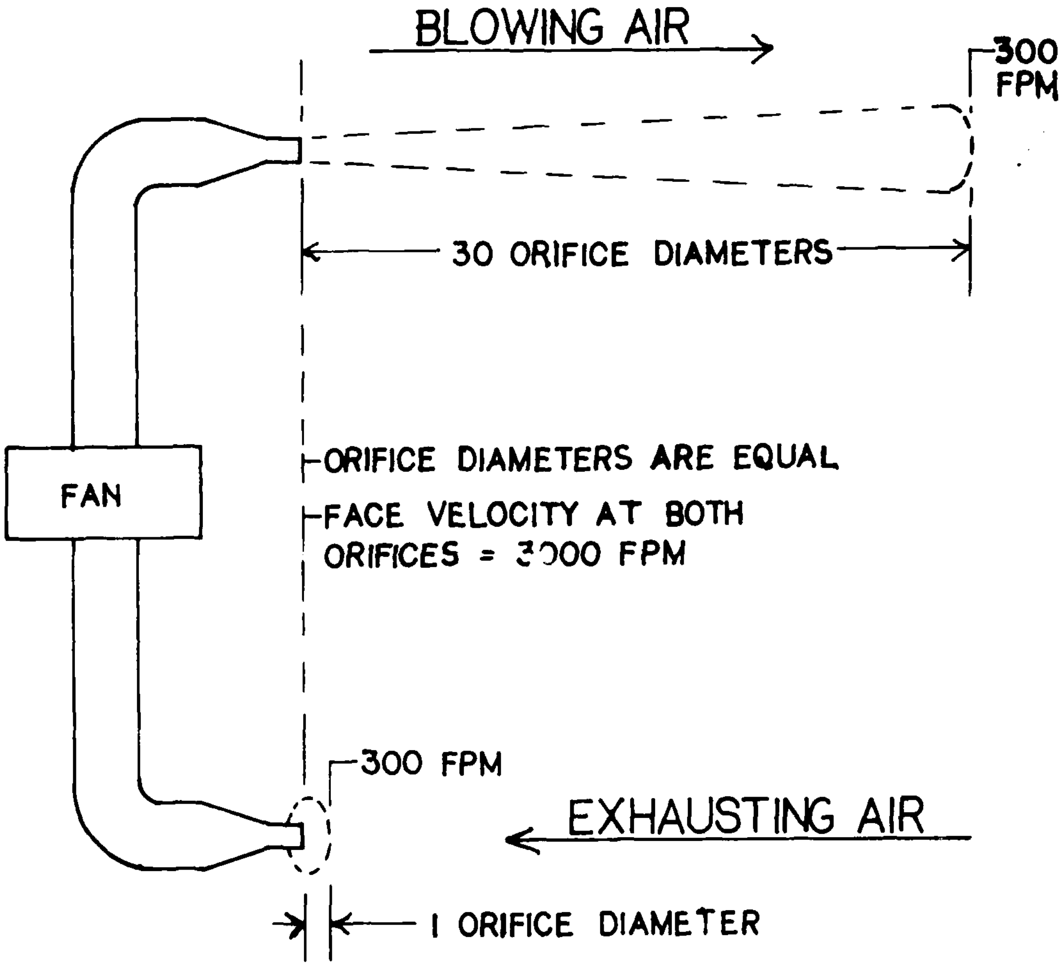

Figure 4. Flow characteristics of blowing and exhausting air.

Assuming a volume delivery rate of 0.03 CFM through a handpiece spray orifice 0.027 inch in diameter, a face velocity of approximately 7500 FPM is calculated. At a distance of 30 orifice diameters (0.8 inch) from the spray orifice face, the velocity should be approximately 750 FPM. To effectively capture this debris-containing aerosol at a nominal working distance of 0.5 inch from the orifice of the evacuator tip, the evacuator-tip exhaust velocity should at least equal, and preferably exceed, the spray velocity. By applying the specification values to the following exhaust-flow equation:

$$V = \frac{Q}{10X^2 + A}$$

where: V = Air velocity (FPM) at X distance from the face of the evacuator-tip orifice
X = Distance (feet) from the evacuator-tip orifice face
Q = Air volume delivered (CFM)
A = Evacuator-tip orifice area (ft^2)

the following velocities are found for the distances shown:

0.25-inch distance from evacuator tip--3204 FPM
0.375-inch distance from evacuator tip--1424 FPM
0.5-inch distance from evacuator tip--800 FPM

From these values, the velocity of exhausting air can be seen to vary almost inversely with the square of the distance from the face of the oral-evacuator-tip orifice. These figures also mathematically verify the principle shown in Figure 4.

A velocity of 800 FPM at a nominal working distance of 0.5 inch, with increasing velocities at shorter working distances, has clinically been sufficient to control the debris-bearing coolant aerosol produced by the high-speed handpiece.

The vacuum pressure specified for the HVE system is 8-inHg draw. This pressure and the 15-CFM volume are the two essential factors of a working HVE system. Clinical experience has dictated the 8-inHg value to supply sufficient vacuum pressure to scavenge pooled liquids and solid debris from the operating site. This level of draw is also necessary to lift effluent through the piping to the centralized separating device. In some installations, especially retrofit situations, pipes for a central HVE system must be installed overhead in the attic space. In such cases, the vacuum pressure must be sufficient to raise the effluent to the central trunk lines. Since 8-inHg draw is the equivalent of 109 inH_2O, the vacuum can lift effluent over 9 feet at each DTR input. Properly trapped, this installation method is very successful but has the disadvantage of higher cost for installation.

HVE System Components

The system begins with the clinical end items in the DTR for hands-on use by the treatment team. These include the suction tips, hand valve, hose, and solids collector. The remainder of the system serves the central function for all DTRs. These components include a custom-engineered plumbing network, a central collector/separator, two turboexhausters, and an air exhaust directed to the atmosphere external to the facility. In new construction of dental facilities, each DTR will have several inlets to the central piping network. These will usually be stubbed into the wall-mounted utility centers located on each DTR sidewall. Retrofit and remodeling projects may require only one inlet, depending upon casework layout and access to the DTR for pipe installation. These cases often require stubbing into a floor-mounted utility center.

Clinical End Items--HVE tips, valves, hoses, and solids collectors, while considered the clinical end of the system, are not generally provided by the central system manufacturer. To be physically compatible with the dental delivery system used, these items are produced by the delivery-system manufacturer. They are usually found as part of the assistant's fixed-instrumentation-package option and should be installed on an assistant's mobile cart when DTR size and configuration permit. These clinical end items should be procured from the central-system manufacturer only when such items will be free-standing and independent from the delivery unit or mobile-cart system.

The clinical end of the HVE system should be provided with two hoses and valves. One hose and valve provides scavenging for nitrous oxide equipment during procedures requiring analgesic gas. The second hose and valve with tip serves the normal HVE function. Solids collectors from all unit and cart producers are available with dual hose connections.

Central Piping System--The central piping network and associated equipment are shown diagrammatically in Figure 5. The clinical end of the HVE system is connected to a specifically designed and sized central piping network by individual 0.75-inch pipes known as risers, one for each solids collector in the DTR. Risers begin in the DTR utility center and connect to either a branch or trunk line whose diameter is increased at intervals along its length to equate, in a cross-sectional area, the sum of the cross sections of the risers connected to it. This sizing is essential for continual movement of contained effluent. To further ensure effluent movement and to prevent line stagnation, the end of each branch or trunk line, slightly beyond the last riser connection, must be equipped with a vacuum relief valve. This device lets air bleed into the line to cause effluent movement when clinical inlets are turned off or are operating in minimal number.

Central Separator--All main trunk lines are routed to a central point at the location of the turboexhausters and connect to a manifold at the separator tank inlet. More than one tank may be used, depending on the size of the facility. Sizing criteria are found in DESIGN GUIDANCE in Part II of this report.

Separating tanks are cyclonic type and constructed of noncorrosive, inert materials, preferably glass-reinforced plastic (GRP) because of traces of elemental mercury. Mercury will perforate metal tanks, especially the galvanized variety. Inevitable corrosion will also shorten the life of metal separator tanks. Effluent enters the tank tangentially near the top, under vacuum pressure, and undergoes a swirling action. The liquid portion of the effluent separates centrifugally and settles to the bottom of the tank. Air

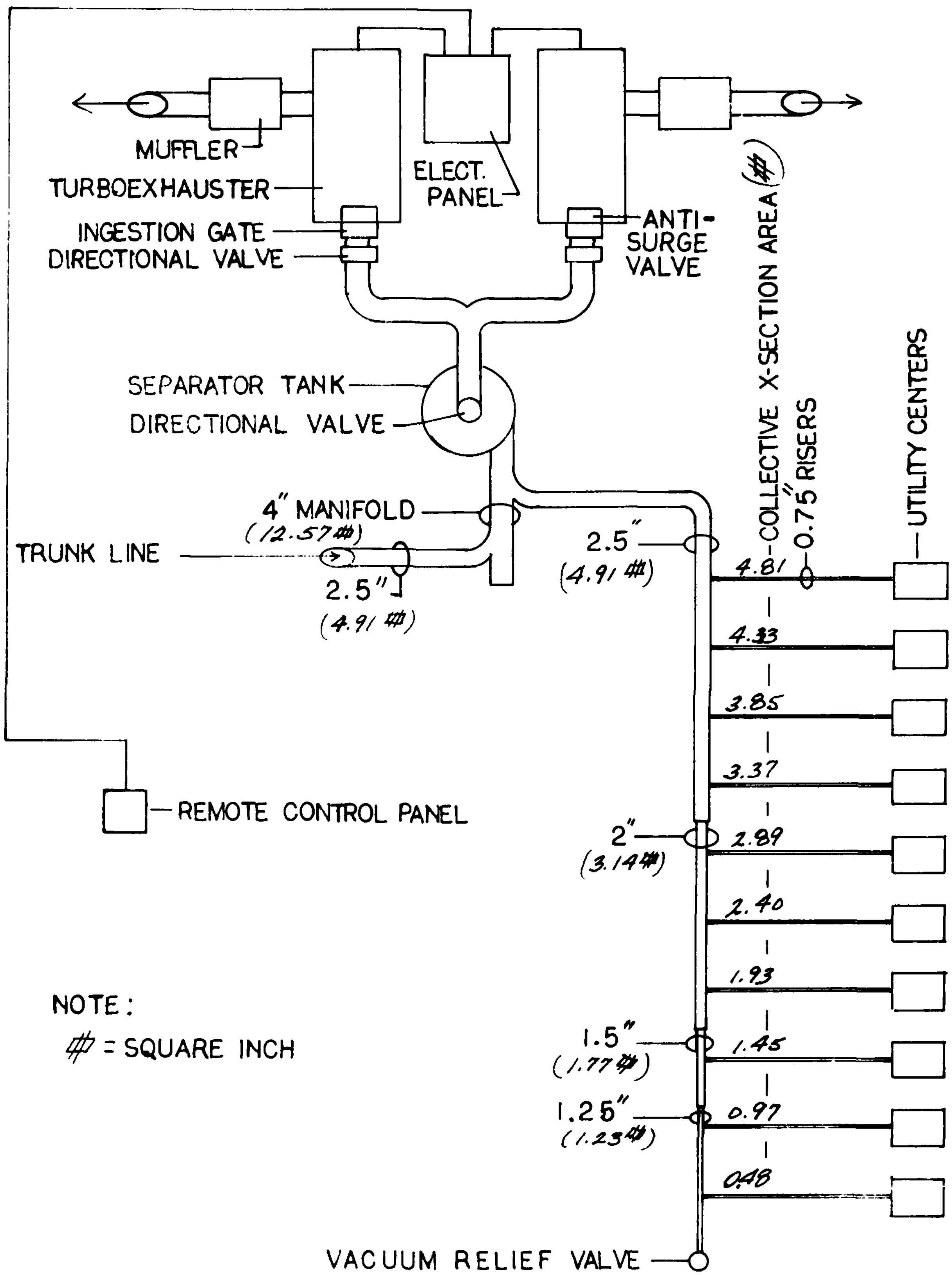

Figure 5. HVE functional diagram.

is drawn from the top of the tank and enters the turboexhauster. The separator tank must have several protective devices to prevent accidental entry of liquid into the turboexhausters. First, the tank is equipped with an electrically operated liquid-level sensor with detectors at the full and empty positions. In a single-tank installation, when the full condition is detected, the turboexhauster automatically shuts down for a few minutes, until the tank drains, and then restarts. In a multitank installation, the detector closes a solenoid valve at the top of the tank until the tank automatically drains and returns to service; meanwhile, the system continues to operate using the other tank. Single-tank installations are sized so that HVE service is not interrupted for draining during a normal duty day.

A second, or backup, safety device is required--a float cutoff at the top of the tank which stops effluent entry into a full tank until it is emptied. If the shutoff float fails, the turboexhauster must be manually switched off for the tank to drain.

All tanks are equipped with a gate or swing-type check valve at the bottom drain. While vacuum pressure is in the tank (system operating), the check valve remains closed to maintain vacuum. When vacuum ceases, as when the turboexhauster is shut down or the air-outlet solenoid closes, the drain check valve falls open and the tank drains.

Each tank is equipped with an automatic clock-controlled internal washdown system (autoflush). The controller clock is set to activate an adjustable-time washdown cycle during off-duty hours to flush and remove sludge to prevent stagnation and buildup of precipitates inside the tank. Criteria for tank capacity needed for various facility sizes are found in DESIGN GUIDANCE in Part II of this report.

Drain Facility--Although not a true component of the HVE system, drainage to sewer is an important aspect of system installation and must be thoroughly considered in the planning stage. In planning for new facility construction, a 12x12x6-inch floor sink with a 3-inch drain must be placed at or very near the location of the separator tanks. This size floor sink can handle the gravity drain discharge. In any construction or remodeling where a floor sink cannot be used and effluent must be moved overhead, a high-pressure pump must be included as part of the system. A sump pump should not be substituted for the high-pressure in-line pump. Sump pumps are not reliable enough nor are they capable of sufficient performance to handle tank drainage. The in-line high-pressure pump is controlled by the liquid-level sensors in the separating tank(s) and can empty a tank without interruption of HVE service. When overhead pumping of drainage is required, include the high-pressure pump as part of the system equipment.

Turboexhausters--Except for very small clinics, each dental facility will be equipped with at least two turboexhausters. Each will be sized to handle 100% of the calculated HVE requirement for the whole clinic. The very heavy dependence of modern dental techniques and associated equipment on a reliable HVE system dictates a 100% backup system in case of turboexhauster breakdown. The two turboexhausters will be used alternately; for example, one used on odd and the other on even days of the month. Alternated use of paired turboexhausters has been reported to provide up to four times the service life of a single unit used daily.

Large turbines required to supply 100% use rate to large facilities are not consistently heavy consumers of energy. When operating with less than the full clinical load, these units do very little work to move air; therefore, their energy consumption is small. Demand is placed on the turboexhausters only when a large number of users are on line. During these brief periods the turboexhauster drive motor is operating at or near its designed current draw, which for systems of this type is a lesser draw than for multiples of small turboexhausters operating simultaneously to produce the same work.

The turboexhausters are installed from the separator tank(s) and parallel to each other. Each exhauster must have in its input line a swing-type check valve to prevent backflow during maintenance or operation of the opposite unit. Each unit must also have in its input line an ingestion gate to regulate the maximum air input to the turboexhauster. This gate is an adjustable butterfly-type valve which provides a finite setting for the 15 CFM at each DTR input and keeps the exhauster from ingesting more air than it was designed for (which would burn out its drive motor due to overload). Located at the first stage of each turboexhauster is an antisurge valve. This is an adjustable mechanical device that bleeds air into the exhauster to maintain a constant level of vacuum pressure in the system regardless of how many using DTRs are on-line. Continual monitoring and compensation for surging by this valve reduces temperature buildup in the turboexhauster, thus enhancing its service life and efficiency.

To provide the 8-inHg draw required by the specification, the turboexhauster must incorporate at least six stages. It must also be of the outboard-bearing design, which means that the exhauster and its drive motor must have independent bases: the turboexhauster must not be supported in any way by the motor. This design provides far greater shaft and bearing life and simplifies realignment of motor and exhauster shaft when bearings must be replaced. Turboexhausters require special noise and vibration control. The exhauster and its drive motor are rigidly mounted on a frame of box-section steel rails. Rubber isolator pads between this frame and the structure floor absorb vibration and prevent its magnification. The inlet pipe and exhaust stack are mounted to the exhauster through resilient piping isolators to prevent vibration and noise transmission into the central system. Each turboexhauster requires a muffler or silencer mounted in-line in the exhaust stack for noise control. These silencers should be the straight-through absorption type to prevent backpressure on the exhauster. Stacks for the exhausters should exit straight through the roof of the housing structure, preferably with no bends or turns, again to minimize backpressure.

The general rule in sizing vacuum generators for the HVE system is to multiply the total number of DTRs in the facility by 15 CFM and then compensate for line losses caused by inherent restrictions in the plumbing and associated equipment. For clinics with up to 20 DTRs, a 10% increase is used. For clinics with more than 20 but less than 40 DTRs, a 15% increase should be used. For larger facilities, a 20% increase may be required to compensate for line losses in very complex central piping systems with many directional turns in the pipe runs. The corrected total CFM value is applied to the sizing chart in DESIGN GUIDANCE in Part II of this review. From this chart the proper horsepower/CFM combination is selected.

Electrical Controls--The turboexhausters are controlled via a remote control panel located in a convenient, easily accessible area of the facility. The most popular installation site for this panel has been near the records and reception area, where staff personnel are always present during normal duty hours. This location is also convenient for the person in charge of quarters and the duty officer handling emergencies during other than normal duty hours. The panel contains a system vacuum gauge and on-off indicator lights and power switches for each turboexhauster.

The remote control system is powered by a low-voltage transformer (24 VAC) and requires only small-gauge (#14) wiring between the panel and the equipment site. The equipment manufacturer must provide an electrical control panel with magnetic starters to provide high-voltage switching of the turboexhauster motor by the low-voltage signals from the remote control panel. The electrical control panel is located at the same place as the turboexhausters.

Small-Facility HVE Systems

For very small clinics (2-4 DTRs), a pair of high-quality water-ring (or water-injected) pumps may be used to provide HVE service. When the pumps are selected, the capability of each pump to provide 15 CFM, with 8-inHg draw (vacuum pressure), at each DTR must be ensured. The plumbing and remote-control criteria that apply to the turboexhauster system also apply to the water-ring pump substitute system. Water-ring pump systems are available with the central separator incorporated in the pump-cabinet enclosure. Since the separator does not have an automatic drain feature, clinic personnel must organize a schedule for manual emptying and changing.

High-Vacuum Oral Evacuation System (HIVAC) for Oral Surgery, Periodontics, and Endodontics Treatment Rooms

The HIVAC system is designed to build and sustain high vacuum pressures at very low airflow. Specifically, this system provides for safe removal of viscous fluids, suture material, and hard- and soft-tissue debris from surgical wound sites, without damage to normal tissue or dislodgement of freshly formed blood clots. Inlets to this central system are located in oral surgery, periodontics, and endodontics DTRs: all disciplines that create open surgical wounds in their treatment procedures. All inlets are connected to a central piping network that operates as a dry-type system, with individual separators and related hardware located in each using DTR. The vacuum generators for this system are water-injected (or water-ring) pumps.

Operational Parameters

The 1-2 CFM and 15-20-inHg vacuum power are classic values established through many years of operating room experience. The very high vacuum pressure is required to scavenge viscous fluids (such as blood and saliva) and grasp tissue debris for removal from the surgical site. The very low airflow is necessary to prevent grab and injury of delicate soft tissues and accidental removal of clots that are forming. This combination of air supply and vacuum pressure provides a much slower acting system--ideal for the delicate function it serves--than the fast-acting HVE system previously described.

HIVAC System Components

For this system only one inlet is provided for each using DTR. In new construction, the inlet is equipped with a faceplate and quick-disconnect valve and is located with the medical gas outlets on the entry wall of the DTR. Retrofit and remodeling projects may call for a different location depending upon installation access, casework, and equipment layout. All inlets are connected to a specially sized and engineered central piping network leading to a vacuum reservoir and pumps. The type and location of the clinical end items (used by the treatment team in patient care) within the DTR are very different from those of the HVE system previously described.

Clinical End Items--The clinical end items for the HIVAC system are free-standing; that is, they are not normally attached to other pieces of dental equipment (as are components of the HVE system). As a result, these items can be supplied by the manufacturer of the HIVAC central system or from other sources. All components of the clinical end items should be procured from the same source to assure compatibility within the assembly. All parts, incuding the quick-disconnect fittings for the regulator and wall inlet valve, must be hospital grade to assure good performance and service life. The clinical end items include the surgical tips; hose; a shatter-resistant suction bottle assembly with wall bracket, cap, and float; an overflow safety trap; and a suction regulator and gauge assembly. The suction bottle hangs from the wall by its own bracket, and to the bottle is attached the suction-tip hose and a hose connection to the safety trap. The safety trap is attached directly to the bottom of the regulator, and the regulator is attached by a mating quick-disconnect fitting to the wall-mounted vacuum service inlet. When not in use, the clinical end items are disconnected as a unit and stored.

The regulator must have an exterior knob to allow hand adjustment of vacuum from 0 to full capacity. The regulator also must contain an easily readable gauge for monitoring the vacuum (its agreement with the set adjustment).

In the vacuum scavenging of blood, much foaming can occur in the suction bottle. If the suction bottle float is not activated by foam, the contaminant spills over into the central piping. To prevent this, an overflow safety trap must be included in the system.

Central Piping System--The central plumbing network and associated equipment are shown diagrammatically in Figure 6. The vacuum inlet valve (station inlet) located on the wall of using DTRs has a quick-disconnect fitting that receives and holds a mating fitting on the rear of the regulator. When the clinical end items are removed from their wall mounting and the regulator is unplugged from the inlet valve, the valve must automatically close to seal the central system against leakage. Unlike the HVE, the HIVAC is a sealed system. That is, air enters the central piping only through the regulators in the using DTR during patient treatment procedures. The system is a dry one and therefore needs no bleed air to carry pipeborne effluent. The wall-mounted inlet valves are connected to the central network by 0.5-inch riser pipes. All branch and trunk lines to which the risers are connected are a constant size. The size of these lines is determined by the size of the vacuum reservoir inlet. This inlet size varies with the size of the reservoir/pump assembly required. Using a constant size for trunk lines adds to the reservoir effect, increasing the efficiency of the system.

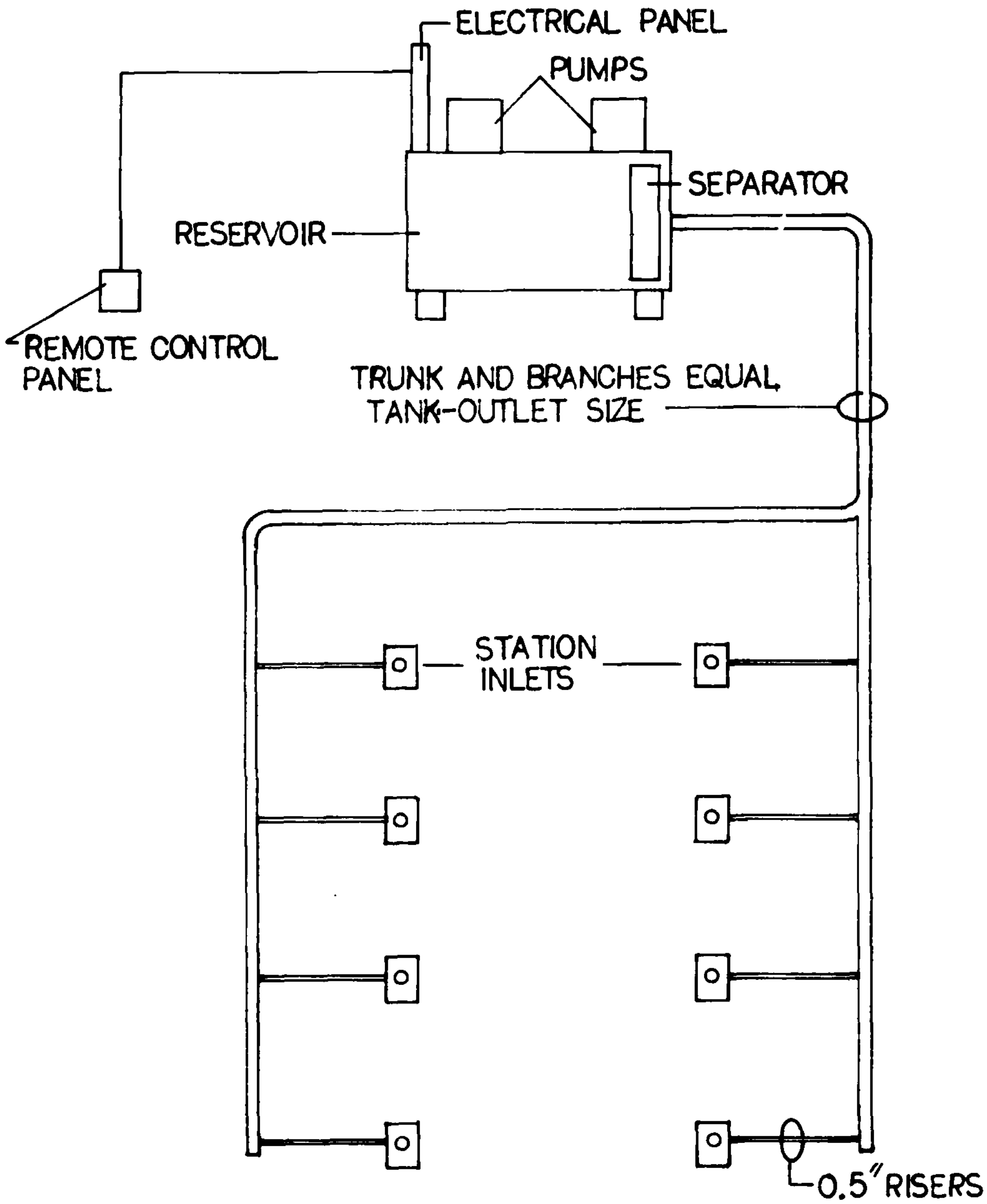

Figure 6. HIVAC functional diagram.

Vacuum Pumps--All HIVAC systems will have two water-ring (or water-injected) pumps, either capable of the full design load of the system. The electrical panel to control the pumps must have the capability to automatically alternate the pumps for each start. The pumps are connected in parallel, and each has a swing-type soft-seat check valve in its input to prevent backflow from the unit not in operation. Dual vacuum switches, mounted on the vacuum reservoir tank, monitor the vacuum. One pump pulls the system down to the specified vacuum pressure and then shuts down until using DTRs bleed off enough vacuum to cause the other pump to operate, thus maintaining the preset vacuum pressure.

Like the sizing criteria for the HVE system, the HIVAC system size is based on total volume capacity required. The number of using DTRs (oral surgery, periodontics, and endodontics) is multiplied by 2 CFM to obtain the total load requirement, and the product is corrected by adding 10% to compensate for line loss (internal friction of the plumbing). The corrected volume is then multiplied by a use factor of 0.8, and the result is used to select the proper pump capacity. Pump size is selected so that each pump is capable of the above calculated load. These systems are available ready to tie in to piping and electrical supplies. The sizing chart for these units is given in DESIGN GUIDANCE in Part II of this report.

Pumps continually ingest water to maintain the vacuum-generating capability. Immediately after leaving the pump, the water is discharged as an air/water mixture into a separator. The separated air and water are exhausted to a piping vent and sanitary sewer drain respectively. Pumps must be hospital grade, of heavy-duty cast-iron construction with corrosion-resistant rotors to enhance longevity. Pumps are mounted directly on the vacuum receiver or reservoir.

Vacuum Reservoir--The vacuum reservoir (or tank or receiver, as it is often called) must be constructed of corrosion-resistant material. Although the system is the dry type, the high-humidity air it ingests will allow some **condensation in the reservoir. For this reason, the reservoir must be equipped with a manual valve at its lowest point for occasional draining.**

The only purpose of the reservoir is to serve as a vacuum ballast, much as does the tank in a compressed-air system. The reservoir allows the buildup and containment of a reserve of vacuum to prevent rapid cycling of the pumps and surging of the vacuum service. It must be constructed to withstand the specified vacuum plus the safety margin required for such devices and must include necessary control devices (vacuum sensors and switches for automatic pump operation), threaded inlets and outlets for associated pipes, drilled feet for site anchoring, and all other parts and devices included in the complete system.

Electrical Controls--Main-power on-off switching for the HIVAC pumps is provided by a remote control panel like that for the HVE system. Unlike the HVE system, the HIVAC system does not run continuously. These pumps are intermittently switched on and off by the pressure-sensitive devices on the vacuum reservoir that respond to the clinical demand. The devices act through the magnetic starters in the electrical control panel supplied with the equipment package. The panel for the HIVAC pumps must also provide an alternating feature. That is, each time the vacuum-pressure sensors call for a pump to start, the control panel must automatically alternate the pump in service. Both the remote-control panel and the tank-mounted electrical control panel should be supplied as part of the system package to assure compatibility.

High-Volume Evacuation System for Base Dental Laboratories (HVEL)

This central system is specifically designed to collect, separate, and filter dry dust and cutting, grinding, and polishing particulates from the dental laboratory work space. Inlets to this system are located at the technicians' sitdown benches and at pieces of stationary abrasive, grinding, and finishing equipment. All inlets are connected to a centrally plumbed network routed to a central separator and filtering device. Vacuum for the system is produced by a high-speed belt-driven turboexhauster.

Operational Parameters

Long experience in particulate scavenging in industrial processes provides an excellent background for determination of essential factors for the HVEL system. These factors have been established at airflow volumes of 60 and 150 CFM at 3-inHg draw. The 60 CFM applies to the inlets located at the technicians' sitdown task areas, and the 150 CFM is used for scavenging the hoods of stationary equipment such as air abrasive units and polishing/finishing lathes. These very high airflow volumes are required so that the exhausting air will have the velocity needed to collect and remove airborne particulates. Air velocities at these airflow volumes do generate noise; however, measured on a time-weighted basis, they pose no danger of hearing impairment. The system requires only a relatively low level of vacuum pressure to move dry aspired debris through the central piping to the separator/filter.

HVEL System Components

The HVEL system begins with the individual inlets in the front face of the service ledge located at the rear of all dental laboratory casework (cabinets and benches). These inlets are connected to a central piping network specifically sized for each installation. This network connects to a central filter/separator unit evacuated by a belt-driven high-speed turboexhauster.

Inlet Fixtures--The HVEL system uses two inlet sizes. A 1.5-inch inlet is used to exhaust the hoods and interiors of fixed equipment such as sand/shell blast cabinets, microabrasive cabinets, polishing and finishing lathes, and high-speed grinders. These inlets are designated to provide 150 CFM of exhausting air. The technicians' sitdown task benches are equipped with 1.25-inch inlets designated to provide 60 CFM of exhausting air to handle particulate scavenging from slower speed hand grinding and cutting. These inlets provide vacuum for the small fishmouth-type hoods located on the bench top. All inlet fixtures include a top-hinged, vertically swinging cover lined with neoprene or rubber. When not in use, the cover swings down to seal the inlet orifice against leakage and unnecessary high-velocity-air noise.

The cross-sectional area of the inlets to the central system governs the CFM of air passing through that particular inlet size. The capacity of the turboexhauster limits the total usable capacity of the system.

Central Piping Layout--Central piping and associated equipment are shown diagrammatically in Figure 7. Like that for the HVE, branch lines of the HVEL system are progressively increased in cross-sectional areas by standard pipe size to equate the sum of the cross-sectional areas of the inlets attached. For calculation purposes, the 1.25-inch inlets have a cross section of 1.23 square inches. A correction factor of 1.1 to compensate for line friction loss is applied, bringing the design cross section to 1.35 which is used to calculate the progressive cross section. The 1.5-inch inlets measure 1.77 square inches in cross section and are compensated to 1.95 square inches for design use. The sum of the cross-sectional areas of all branch lines is used to select the final and largest pipe, the trunk line, that connects to the filter-separator. To balance the system, the trunk line must be extended past the intersections of all branches to a point in a crawl space or to the exterior of the facility. At the end of this trunk run, an air volume relief valve is installed. This valve is sensitive to vacuum pressure (inHg draw) which operates a large-capacity air gate within the body of the valve. When few using inlets are on line, the air gate senses a tendency toward increased vacuum pressure and bleeds air into the system to prevent excessive volume intake at the operating inlets. By its ability to respond to fluctuating tendencies in vacuum pressure as inlets come on and go off line, the air volume control valve helps to maintain designed airflow through the inlets, reduces high-velocity-air noise, and in the large trunk line provides air velocity necessary to move ingested particulates downstream to the filter-separator unit. The remote location of the air volume valve and its attached muffler is required because of the potential for high-velocity-air noise.

Filter-Separator--The main trunk line of the HVEL system is plumbed directly to the central filter-separator located close to the turboexhauster supplying its vacuum. The filter-separator is a cyclonic type that swirls the incoming debris-laden air to cause separation. Debris is dropped into a wheeled, removable container at the bottom of the unit. The air is taken through a system of filter bags before leaving the top of the unit on its way to the turboexhauster. The filter-bag system is equipped with an electrically operated shaker that drops accumulated dust from the exterior of the bags into the debris container. The control for the shaker should be located with the turboexhauster remote control panel at a convenient site within the laboratory. A daily shakedown of the bag system maintains the efficiency of the separator. The debris container is attached to the bottom of the separator by a cam lock that seals against vacuum loss and facilitates removal for emptying.

Criteria for selecting filter-separator size are in DESIGN GUIDANCE in Part II of this report. Nominal physical dimensions for these units range from 72 to 120 inches in height and from 24 to 28 inches in diameter. Weight range is 250-720 pounds. Filter-bag area range is 40-300 square feet.

In laboratories equipped with sand-blasting units without a built-in filter system, an in-line primary filter must be installed between the sandblaster exhaust outlet and the HVEL input. Primary filters, when required, are considered part of the HVEL system and should be supplied with it.

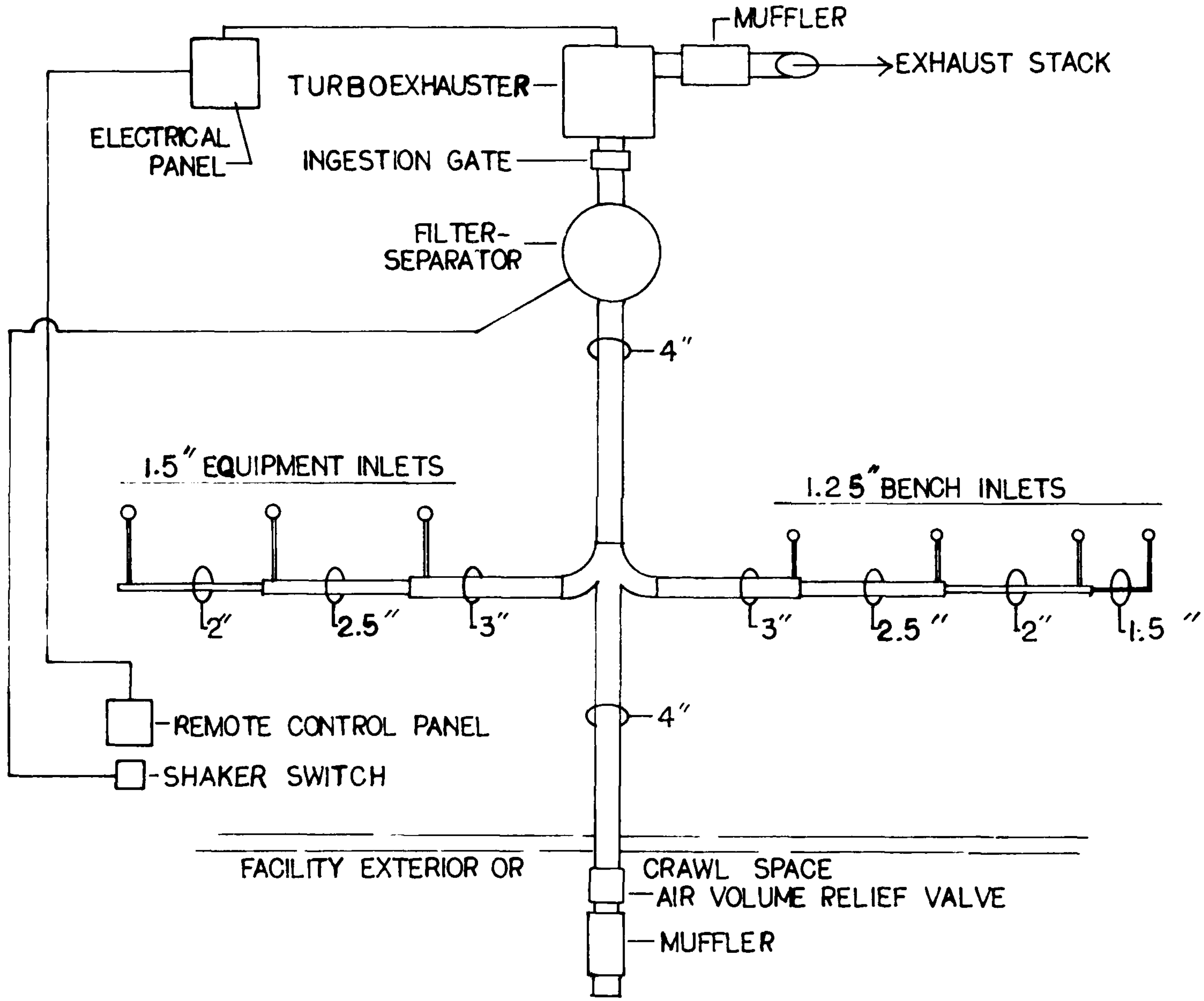

Figure 7. HVEL functional diagram.

Vacuum Generator--The vacuum generator for the HVEL system is a single belt-driven turboexhauster. Because this system has a low level of operational stress imposed on it and is a nonclinical item (with reduced significance in normal use as well as in a contingency situation), a second or backup vacuum generator is not justified.

The turboexhauster has fewer stages than its counterpart in the HVE system because of the comparatively low vacuum pressure specified (3 inHg) for the HVEL. The air volume requirement, however, is much higher than for any of the other dental evacuation systems. To provide this increased airflow, a belt-driven system allows more rpm by the turboexhauster. An added advantage is that the belt drive provides a convenient and economical method for adjusting the rpm (therefore, the airflow) to fine tune the system.

The air volume relief valve described under Central Piping Layout serves as the antisurge valve for the HVEL. Since the system does not ingest liquids, vacuum relief valves are not required at the ends of branch lines.

As with the HVE, the HVEL system is equipped with an ingestion gate before the first turboexhauster stage. This gate prevents ingestion of air volume above that for which the system was designed. Larger airflow produces increased load on the turboexhauster drive motor, causing it to overdraw electrical current beyond its rating and thus burn out.

The HVEL unit requires pipe and base-frame vibration isolators and air-outlet mufflers as described for the HVE turboexhausters.

Electrical Controls--The HVEL turboexhauster is switched on and off via a remote control panel installed in a convenient location within the laboratory. As with the HVE, this low-voltage remote panel switches the turboexhauster's magnetic starter, located in the electric control panel at the exhauster. The remote panel contains stop and start buttons, a visual on-off indicator light, and a vacuum pressure gauge (inH_2O). The comparatively low vacuum pressure of the HVEL system is more easily displayed by the inches-of-water gauge (1 inHg = 13.6 inH_2O) than with an inches-of-mercury gauge as used in higher vacuum pressure systems.

A conventional 115-VAC switch is required, separate from but near the remote panel, to control the filter-bag shaker motor installed on the central filter-separator.

Environmental-Janitorial Vacuum System (EJVS)

The EJVS is an add-on system designed to provide a safe and efficient central vacuum for recovering toxic or hazardous materials such as elemental mercury. It is also a safe and efficient adjunct for general housekeeping in areas where mercury might be a background contaminant, as well as in all other areas of the facility. Utilizing vacuum produced by the HVE system turboexhausters, the EJVS is economical to install and operate and replaces a requirement for other commercial and vaporproof cleaning equipment. In facilities where housekeeping is contracted, costs should be less than if the contractor were required to provide vacuum cleaning equipment, especially the vaporproof type needed for cleaning areas where mercury is used. The EJVS is equipped with wheeled, portable wet-separator tanks to provide a wet-dry vacuum cleaning capability and uses commercially available cleaning hoses and implements.

Operational Parameters

Using the turboexhausters of the HVE, the EJVS system operates at 8-inHg vacuum pressure. The other essential factor, volume of airflow, is governed by the number of hoses operating at one time. The usual flow is between 100 and 150 CFM. Both of these factors exceed those of a commercial portable vacuum cleaner.

EJVS System Components

Except for its vacuum source, the EJVS is similar to other central vacuum systems used in residential and commercial structures. Strategically placed inlets lead to a properly sized piping network, terminating at a filter-separator. The unique feature of the EJVS is its use of the HVE turboexhauster for vacuum to drive the system.

Wall Inlets--Inlets to the EJVS are commercially available wall valves constructed of stainless steel. Nominal dimensions of the frame and door are approximately 4.6x4.6 inches. The assembly has beveled edges for safety and protrudes approximately 0.5 inch from the wall. The door is vertically swung and lined with neoprene to effectively seal the 1.5-inch orifice when not in use. Wall inlets are the nonautomatic type (no vacuum generator switch) since the turboexhausters powering the system are switched from a remote panel.

Central Piping System--The individual wall inlets are generally connected by 1.5-inch pipe to a 2-inch branch line. The 2-inch branch line can handle two users without appreciable drop in air volume through the hoses and cleaning implements and is sufficient for a suite or module of DTRs. Branches from suites and modules should connect to a 3-inch trunk line leading and connecting to the filter-separator.

Central Separator--Main trunk line(s) connect to a cyclonic-type dry filter-separator identical to that used for the HVEL system. A remote switch to control the filter-bag shakedown motor should be located near the remote panel controlling the HVE turboexhauster. The filter-separator is located at or very near the turboexhauster, not in an area of frequent traffic. Therefore, to ensure against decreased efficiency and ultimate damage from neglect, a definite schedule must be set up for emptying its collection container.

Vacuum Generator--Vacuum for the EJVS is provided by either of the HVE system turboexhausters. Since these vacuum generators exhaust to the atmosphere exterior to the facility, the EJVS is ideal for handling toxic material spills such as elemental mercury. Any vapor generated in pickup is safely disseminated outside the facility.

Accessories--Each facility should be provided with at least one mobile wet-pickup caddy. This portable device is a two-wheeled 12-gallon tank with handle. It is equipped with a short jumper hose for connection to a wall inlet and is used with 30-foot-long 1.5-inch vacuum hoses to pick up liquid spills, washes, or other wet duty. The caddy tank has a built-in float to prevent overflow and an expansion-plug drain for emptying. The caddy should have implement tips that include a master shoeholder with shoes for smooth floors and carpets, a squeegie shoe for wet pickup, a crevice tool, a dusting brush, an upholstery tool, and a 5-foot-long aluminum S wand. The number of hoses and implements is determined by facility size. DESIGN GUIDANCE in Part II of this report offers further information on quantity.

Electrical Controls--The only electrical control required for the EJVS is a switch for the filter-separator filter-bag shaker motor. This switch can be installed at any convenient location, preferably near the remote-control panel for the HVE system turboexhausters. This switch is usually a 115-VAC type similar to that used for room-ceiling light fixture control and may be wired directly to the shaker motor without relays or magnetic starters.

Equipment Acceptance and Related Documentation

After any of the four systems discussed have been installed, performance tests must be made. These test results determine whether or not the systems are acceptable to the responsible authority. Equipment or assembled systems that do not conform to the design guidance given in Part II of this report should not be accepted for use. The contractor is responsible for making any corrections necessary for the systems to function properly. Performance tests are a very important quality-control step and must be followed closely. Testing details are outlined in ACCEPTANCE TESTING in Part II of this report.

Another very important part of equipment and system installation is documentation containing clear and concise operating and maintenance instructions. These documents are the key to continuous proper use and care of the systems as personnel turnover occurs. Copies of these documents should be made permanent records in both the dental facility and the medical equipment organization responsible for maintenance and repair of the systems. Details of documentation for which the contractor or installer is responsible are found in ACCEPTANCE TESTING (Operating and Maintenance Instructions Required for All Systems) in Part II of this report.

PART II

SPECIFICATIONS

High-Volume Oral Evacuation System (HVE) for Dental Treatment Rooms

Standard Products--The central HVE system shall be composed of standard manufactured products, complete with all devices normally furnished and any other devices required herein. Turboexhauster units essentially shall duplicate units that have performed satisfactorily in a central oral evacuation system for at least 2 years.

Turboexhausters--Turboexhausters (vacuum turbines) shall be self-governing, multistage, centrifugal type, and of outboard design (bearings on both ends of the exhauster shaft). The turboexhauster shall operate at a speed not to exceed 3,600 rpm and shall be connected to its driving motor by a flexible coupling to allow easy removal of motor or exhauster for maintenance. No belts, pulleys, or gears shall be allowed as a coupling method. The exhauster shall have a minimum of two self-aligning radial bearings; one at the front and the rear of the exhauster. Bearings may be sealed, have grease fittings, or have oil-cup lubrication. To enhance their longevity, the manufacturer shall include a fan connected directly to the exhauster shaft in front of all bearings to create a flow of air over the bearings while the unit is operating. A fabricated steel coupling guard encompassing the flexible coupling and bearing cooling fan shall be installed between the motor and turboexhauster.

Power required to operate the exhauster shall be in direct proportion to the volume of air exhausted and shall not exceed the normal motor rating. The vacuum produced shall be substantially constant throughout the operating range of the exhauster to insure uniform results regardless of the number of inlets used below the design level of the exhauster.

Turboexhauster cases shall be cylindrical in design and constructed of heavy-gauge sheet steel, rigidly welded at all seams or sections. Inlet and exhaust connections shall be tangential to the exhauster casing and shall be sized so as to allow air to move freely (within operational range) through the exhauster, without flow restriction of any kind. The turboexhauster input shall have an ingestion gate (valve), a directional flow valve, and an anti-surge valve. The exhauster output shall have an exhaust silencer.

All pipes shall be connected to the turboexhauster through pipe isolators (flexible sleeve connectors). The exhauster shall be constructed with not less than 0.125-inch internal clearance throughout so that transient dust or foreign particles will not cause damage. Impellers shall be constructed of built-up sheet or cast high-tensile-strength aluminum alloy, smooth on all surfaces to prevent unequal deposits of dust or dirt on the surfaces (and thus imbalance). Without exception, impellers shall be of the backward-curve airfoil design to provide maximum performance throughout the entire operating range. Impellers shall be securely attached to the exhauster shaft by set screws or clamp-type hubs of a high-tensile-strength material. Each impeller shall be balanced individually; and the complete turboexhauster, including motor, shall not exceed 1.5 mils of vibration when given a running balance test.

Each turboexhauster shall have a minimum capacity, rated in standard cubic feet per minute (SCFM) at standard air conditions (14.7 psig and 70°F (21°C)), commensurate with the production of not less than 8-inHg vacuum and 15-CFM airflow for each DTR in the specific facility design under consideration. The turboexhausters shall be sized to produce the above designated performance standards at the above-sea-level elevation of the proposed installation site.

Motor--The motor for the turboexhauster shall be of a standard National Electrical Manufacturers Association (NEMA) 3,550 rpm, T-frame, dripproof design; 208/230/460 VAC, 3 phase, 60 Hz; with either sealed or lubricatable bearings. When the motor is operating, its temperature shall not rise more than 40°C (72°F). The motor must be easily removed from the turboexhauster for servicing.

Isolation Pads--Each turboexhauster shall be mounted on isolator pads approved and furnished by the manufacturer. The pads shall not be bolted to the floor or any other device.

Pipe Isolators--Flexible rubber-coupled band-sealed clamps shall be furnished to isolate the turboexhauster from the piping. Couplings shall be sized in accordance with the exhauster's intake and output connections. These flexible sleeve connectors shall be provided with fabricated steel coupling guards.

Ingestion Valve--The input of each turboexhauster shall have an ingestion valve (manufacturer's design) to prevent exhauster overload through the operational range. The ingestion valve may be built in or added to the first stage of the exhauster turbine and shall be preset by the manufacturer during certification testing.

Directional Flow Valve--The input of each turboexhauster shall have a directional flow valve of the nonrestrictive type, to prevent backflow of air when two or more exhausters are installed. The directional flow valve will allow an exhauster to be isolated for service, without restrictive manual cutoffs needed in the input line.

Antisurge Valve--The input of each turboexhauster shall have a mechanical-type antisurge valve that will operate automatically throughout the exhauster's designed range. This valve shall not depend on electrical controls of any kind but shall continually sense the negative pressure within the exhauster and maintain a predetermined, operational level of inches-of-mercury draw. The antisurge valve shall be installed on the first stage of the exhauster turbine and be preset at the manufacturer's facility during certification testing. This valve may be mounted in conjunction with the directional-flow valve and shall be equipped with a silencer to attenuate air noise.

Exhaust Silencer--Each turboexhauster shall output to a separate air discharge silencer of the open-bore expansion type. No interior baffling or shrouding shall be permitted. The silencer shall satisfactorily attenuate air noise to a level below 85 decibels.

Repair Items--A turboexhauster bearing and coupling kit shall be furnished with the delivered system and shall consist of one set of exhauster bearings and one complete motor/exhauster flexible coupling, all of the same size and design as those supplied with the turboexhauster. The kit shall also include complete installation instructions for repair kit items.

Controls--Electrical controls for each turboexhauster shall consist of a combination across-the-line magnetic starter with time-delay fused disconnects, a running-hour meter to indicate the number of hours the unit has been in operation, a stop-start button(s); and a red or amber warning light and an audible alarm to indicate shutdown due to fuse failure. Controls shall also include a complete low-voltage (24 VAC) control function with a low-voltage control panel for remote operation of the turboexhauster. Remote panel location shall be as designated for each specific facility design.

The low-voltage control panel shall be of dual or single design as required and shall contain a separate on-off switch for operation of each power unit, a pilot light to indicate operation, and a certified vacuum gauge (inHg) to indicate the vacuum within the system at all times.

Central Wet Separators--The HVE system shall utilize a central wet separator(s). Total separator capacity shall be in accordance with job requirements. Separator tanks shall be freestanding and of one-piece laminated fiberglass-reinforced construction with smooth interior walls. Tanks shall be high-pressure vessels able to withstand a constant negative pressure of 20 inHg. The tops and bottoms of these tanks shall be convex to allow for total discharge of all contents to waste. A tangential inlet shall effect cyclonic separation of air and water. Separator tanks shall be equipped with mechanical overfill protection, which shall be removable for servicing without special tools. Each tank shall be preplumbed with a 360° supply washdown mechanism and automatic drain. Each tank shall be equipped with a solid-state high-low liquid-level sensor. In multiple-tank installations, one tank shall be adjusted to sense 90% of its water capacity and the other tank to sense 100% of its capacity, to allow for nonsimultaneous discharging and, therefore, uninterrupted HVE function to the clinical facility. Each sensor shall control a 120-VAC electrically operated solenoid valve to control the outgoing airstream from the separator tank to the turboexhauster. These valves shall have an inside diameter of at least 2.5 inches. The system shall include a 120-VAC solid-state automatic-flush clock-controlled mechanism. The mechanism shall effect a complete washdown of the interior of the separator at any predetermined time of day or night. Washdown time shall be adjustable for not less than 5 or more than 180 seconds. The cold-water supply to the autoflush unit shall contain an in-line filter equipped with 40-mesh stainless-steel screens.

Piping-- All inlets to the HVE system shall begin with 0.75-inch risers, originating in the equipment utility centers of the DTRs. Risers shall connect to branch or trunk lines whose sizes are determined by internal cross-sectional areas. The cross-sectional areas of these lines shall be graduated, increasing toward the vacuum source. The cross-sectional area at any point along the run of these lines shall equate to the sum of the cross-sectional areas of all lines and risers connected up to that point, plus 10% system servicing for up to and including 24 DTRs or 15% for over 24 DTRs. These percentages compensate for line-induced flow losses. All pipes shall be of corrosion-resistant material, have a smooth internal surface, and shall not collapse when installed in an HVE system evacuated to 8-inHg gauge. Piping shall be cut square, with burs removed, and installed with minimum obstruction to airflow. ABS (acrylonitrile butyl styrene) or PVC (polyvinyl chloride) piping shall conform to Schedule 40 or Class 200 specifications. Fittings, supports, and joint assembly shall comply with the National Plumbing Code (NPC). The assembled piping system shall be suitable for the vacuum requirement specified in DESIGN GUIDANCE. Fittings shall be the long-radius type for turns and the wye-type for branches. Piping shall slope not less than 0.12 inch/foot to the separator tanks. The most distant end of each trunk line from the separators shall terminate with a vacuum relief valve. All branches shall enter the trunk line between the vacuum relief valve and the separator tanks so that a constant airstream will be provided through the wet portion of the system to keep liquids moving when all user inputs are closed. Layout and installation drawings with technical data to assure piping system suitability shall be submitted to the Contracting Officer for approval. Couplings, unions, and other disconnecting couplings shall be readily accessible at all times.

Vacuum Relief Valve--The vacuum relief valve shall be mechanically operated--requiring no electrical power, wiring, or switches. The valve shall operate automatically, sensing negative pressure in the system and activating to maintain movement of liquids through the piping system to the separator when input branches are closed. The vacuum relief valve connector shall be 0.5 inch MPT. The valve shall be equipped with a silencer to attenuate air noise to an acceptable level.

Out-of-CONUS Installations--For equipment intended specifically for installations outside of the continental United States (overseas bases), the vacuum-source drive-motor frequency and voltage requirements of this specification shall be changed to ensure compatibility with on-site electrical supply configurations. Such modifications shall not detract from equipment longevity or performance.

High-Vacuum Oral Evacuation System (HIVAC) for Oral Surgery, Periodontics, and Endodontics Treatment Rooms

Standard Products--The HIVAC system shall be composed of standard manufactured products, complete with all parts and devices normally furnished with such systems, and shall include any other parts and/or devices required herein. The system shall essentially duplicate units that have performed satisfactorily as a central high-vacuum oral evacuation system for at least 2 years.

System Configuration--The vacuum-source unit will be essentially a dry-type system, duplex in configuration (2 pumps, 2 motors). Pumps shall maintain a preset vacuum range in a vacuum vessel that is continuous with system piping. An individual separator shall be used at each inlet.

High-Vacuum Pumps--High-vacuum pumps shall be of the water-ring (or water-injection) type. Parts that contact water or effluent in normal operation shall be constructed of noncorrosive materials. Pump impellers or rotors shall be balanced. Each rotor shall be of a divided, or dual (side-by-side, common shaft), configuration with each rotor-half operating in diametrically opposed vacuum and compression sectors within the pump body. Pump/motor units shall be able to maintain a vacuum draw of 20-inHg gauge on the attached vacuum-receiving vessel. Pumps shall be connected in parallel to the vacuum vessel with a flexible connector. The input of each pump shall be equipped with a check valve to prevent backflow during single-pump operation. Each input shall also have an isolation valve gate for use in maintenance procedures. The injection-water supply line to the pumps shall be equipped with an anti-siphon (air gap) device to prevent contamination of the main water supply. Each injection-water branch to each pump shall have a solenoid valve to stop injection-water flow during periods of shutdown. To reduce sound level, a silencer (muffler) shall be provided for the common air-exhaust line for both pumps.

Motors--Drive motors shall be directly coupled to pumps without belts or gears, have permanently lubricated bearings, and be equipped with thermal-overload protection. Motors shall be continuous duty, rated with no more than 40°C (72°F) rise during extended operation. Motors rated 2 HP and below may operate on 208/220 VAC, single phase, or 208/230/460 VAC, three phase. Motors above 2 HP shall operate on 208/230/460 VAC, three phase, for operation economy and longevity.

Vacuum Reservoir (Tank)--The vacuum reservoir shall be constructed of galvanized steel or other corrosion-resistant material suitable for negative-pressure vessel construction. It shall have drilled foot brackets for anchoring and a mounting platform for pumps and motors. A manual drain valve shall be supplied, mounted such that all collected condensate can be periodically drained. The reservoir shall have dual vacuum sensors and switches to start and stop pumps alternately through a duplex alternating magnetic starter. A vacuum gauge shall be supplied on the tank for monitoring the vacuum and resetting the switches for maintenance procedures.

Controls--A complete low-voltage (24 VAC) remote control function shall be provided, with a remote low-voltage control panel for operation of the HIVAC System. This control panel shall be of simplex design and shall contain an on-off switch for pump operation, a pilot light to indicate operation, and a certified vacuum gauge (inHg) to indicate system performance and as a check for system leakage. The control panel shall be prewired by the manufacturer to operate on 24 VAC. A duplex magnetic starter with automatic startup alternation for the pump motor units shall be included. All additional electrical devices to provide manual starting-stopping and reset functions at the vacuum equipment installation site will also be included.

Piping--All pipes must be of schedule 40 PVC or type L copper. All bends for pipe of less than 1.25-inch diameter must be made up as long-radius turns using 45-degree fittings. All bends in pipe of 1.25-inch diameter or larger must be made with standard long-radius fittings intended for drain, waste, and vent (DWV) use.

High-Volume Evacuation System for Base Dental Laboratories (HVEL)

Standard Products--Turboexhauster (vacuum turbine) units shall be standard products, complete with all devices normally furnished and any other devices required herein. Exhauster units essentially shall duplicate units that have performed satisfactorily in a laboratory central evacuation system for at least 2 years.

Turboexhausters--Turboexhausters shall be self-governing multistage, centrifugal type and may be of overhung or outboard design. The turboexhauster shall operate at a speed not to exceed 2600 rpm. The exhauster shall be connected to its drive motor by a V-belt (multiple belt) to allow latitude in exhauster rpm by the manufacturer so that units may be more closely matched in performance and energy efficiency to the calculated design load of various facility sizes. The exhauster shall have a minimum of two radial bearings and a support bracket for its shaft. Bearings shall be grease or oil-cup lubricated. The exhauster/drive motor/connector assembly shall be bolted to a base plate that is isolated from the floor. Power to operate the exhauster at the calculated load shall not exceed the normal motor rating. Power required shall be in direct proportion to the volume of air exhausted. The vacuum produced shall be substantially constant throughout the operating range of the exhauster to insure uniform results regardless of the number of inlets used, not to exceed the design level.

Turboexhauster cases shall be cylindrical in design and constructed of heavy-gauge steel, rigidly welded at all seams or sections. Exhaust connections shall be tangential to the casing. Inlet connections may be axially or tangentially placed. Inlets and outlets shall both be sized so as to allow free movement of air (within operational range) throughout. The exhauster input shall have an ingestion gate at the first-stage impeller and a silencer on the exhaust. The silencer and all pipe connections to the turboexhauster shall be through pipe isolators (flexible sleeve connectors). The exhauster shall be constructed with not less than 0.125-inch internal clearance throughout so that injurious wear from transient dust or foreign particulates will not occur.

Impellers shall be constructed of built-up sheet or cast high-tensile-strength aluminum alloy, smooth on all surfaces to prevent unequal deposits of dust or other foreign particulates on the moving surfaces, thus avoiding imbalance. Without exception, impellers shall be of the backward-curve airfoil design to provide maximum performance throughout the operating range. Impellers shall be safely and securely attached to the exhauster shaft by set screws or bolt-secured clamp-type hubs of a high-tensile-strength material. Each impeller shall be balanced individually; and the complete unit, including motor, shall be given a running balance test and shall not exceed a maximum of 1.5 mils of vibration.

The turboexhauster shall have a minimum capacity, rated in SCFM, commensurate with the production of not less than 3-inHg-gauge vacuum for the number of inlets designated in the laboratory. The turboexhauster shall be sized and powered to produce the designated performance standards at the above-sea-level elevation of the proposed installation site.

Motor--The motor for the turboexhauster shall be of a standard NEMA, T-frame, dripproof design; 1725 rpm; 208/220 VAC, single phase for up to 5 HP; 208/230/460 VAC, three phase for 5 HP and above; all 60 Hz. Motors may be supplied with either sealed or lubricatable bearings. When the motor is operating, its temperature shall not rise more than 40°C (72°F). The motor shall be easily removed for service without disturbing the turboexhauster from its mountings.

Isolation Pads--The platform to which the turboexhauster/motor assembly is fastened shall be mounted on isolator pads approved and furnished by the manufacturer. Pads shall not be fastened to the floor or to any supporting device.

Pipe Isolators--Flexible rubber-coupled band-sealed clamps shall be furnished and used to isolate the turboexhauster unit from the piping system. Couplings shall be sized in accordance with the exhauster's intake and output connections. These flexible connectors shall have fabricated steel coupling guards.

Ingestion Gate--The input of the turboexhauster shall be equipped with a manufacturer-designed ingestion gate (valve) to prevent overloading of the drive motor if the maximum design load is accidentally or temporarily exceeded. The ingestion gate may be built in or added to the first stage of the exhauster turbine, and preset by the manufacturer during certification testing.

Exhaust Silencer--The turboexhauster shall output to an air discharge silencer of the open-bore expansion type. No interior baffling or shrouding shall be permitted. The silencer shall satisfactorily attenuate air noise to a level below 85 decibels.

Repair Items-- A turboexhauster bearing and belt kit shall be delivered with the system. The kit shall include one set each of exhauster bearings and replacement drive belts, all the same size and design as those supplied with the turboexhauster. The repair kit shall also include complete installation instructions for all its items.

Controls--Electrical controls for the turboexhauster shall consist of a combination across-the-line magnetic starter with time-delay-fused disconnects, a running-hour meter to total the number of hours of operation, stop-start button(s), and a red or amber warning light and an audible alarm to indicate shutdown due to fuse failure. The controls shall include a complete low-voltage (24 VAC) remote control function with a control panel for remote operation of the exhauster. The low-voltage remote control panel shall contain an on-off switch for the turboexhauster, a pilot light to indicate operation, and a certified vacuum gauge reading in inches of water (inH_2O) to indicate the vacuum within the system at all times.

Central Separator--The central separator shall be a freestanding unit of heavy-gauge steel and all-welded construction. The separator chamber shall be of the cyclonic type and shall effectively separate and trap all particulate matter contained in the vacuum input. The internal configuration of the separator shall be such that air leaving the cyclonic chamber shall be directed upward through a filter bag(s) to effect final cleaning of the air before its entry into the turboexhauster. The lower part of the separator enclosure shall contain an easily accessible and serviceable debris container. The container shall lock into operating position to form a positive seal between the removable container and the separator enclosure, to prevent leakage of the vacuum system. The debris container shall be removable and reinstallable without the use of tools. The container shall be equipped with casters to facilitate moving for emptying and reinstallation alignment and shall have a pivoting handle to facilitate handling. The separator shall be equipped with a filter-shaker mechanism actuated by an electric motor operating through mechanical linkage to the shaker mechanism. An electrical switch to control the shaker motor shall be on or adjacent to the separator and shall conform to appropriate electrical code. The separator shall be equipped with an easily removed screw- or bolt-fastened access panel to provide easy access for filter inspection and service.

Primary Separator--When necessary to satisfy specific design requirements, a primary separator shall be used in addition to, and ahead of, the central separator. The primary separator shall be of the cyclonic type and shall effect initial separation of abrasive particulates before vacuum air and debris enter the central separator. The primary separator shall be of heavy-gauge steel, all welded-seam construction, and may be freestanding or wall-mounted.

Piping--All piping of the HVEL system shall be sized according to cross-sectional area as specified for the HVE system--piping. All pipes shall be of corrosion-resistant material, have a smooth internal surface, and shall not collapse when installed in an evacuation system evacuated to 5-inHg gauge. Piping shall be cut square, with burs and flashing removed, and installed with minimum obstruction to airflow. ABS or PVC piping shall conform to Schedule 40 or Class 200 specifications. Fittings, supports, and joint assembly shall be of approved type. The assembled piping system shall be suitable for the vacuum requirement given in DESIGN GUIDANCE (HVEL Design Criteria). All fittings shall be of DWV long-radius type. Coupling, union, and other disconnecting fittings shall be readily accessible at all times. Layout and installation drawings with technical data to assure piping system suitability shall be submitted to the contracting officer for approval. The most distant end of the main trunk line from the central filter-separator shall terminate with an air volume relief valve. This valve shall be located on the trunk line so that all entering branches lie between the valve and the filter-separator. The trunk end containing the valve shall extend to the facility exterior or an appropriately ventilated crawl space for the ingestion of possibly a large volume of unconditioned air to prevent overdraw into system inlets when few users are on-line. The valve also provides air velocity in the large trunk line to transport debris to the filter-separator.

Air Volume Relief Valve--The air volume relief valve shall be mechanically operated, requiring no electrical power. The valve shall operate automatically, sensing negative pressure in the system and opening and closing proportionately to maintain designed air capacity to the turboexhauster, depending on the number of inlets on-line. The air volume control valve shall prevent overdraw by the inlets, minimizing high-velocity-air noise in the laboratory enclosure. The valve also maintains air velocity needed in the large-volume trunk line to move ingested particulates to the filter-separator.

Vacuum Inlets--User inlets for technicians' benches shall be 1.25 inches ID and for fixed-equipment locations, 1.5 inches ID, with removable friction-fit adapters sized to receive 3-inch-ID flexible hose. Adapters shall provide an airtight seal when inserted into the vacuum inlet. All inlets shall have attached pivot or hinge-mounted doors. When closed these doors shall provide an airtight seal to close off the vacuum inlet; when open, they shall not interfere with insertion of the adapters with 3-inch-ID hose attached.

Out-of-CONUS Installations--For equipment intended specifically for installations outside of the continental United States (overseas bases), the vacuum source drive-motor frequency and voltage electrical requirements of this specification shall be changed to insure compatibility with on-site electrical supply configurations. Such modifications shall not detract from equipment longevity or performance.

Environmental-Janitorial Vacuum System (EJVS)

Vacuum Source--The turboexhauster(s) installed for the HVE system shall serve as the vacuum source for the EJVS.

Central Dry Separator--The central separator shall be a freestanding dry unit of heavy-gauge steel and all-welded construction. The separator chamber shall be the cyclonic type and shall effectively separate and trap all particulate matter contained in the vacuum input. The internal configuration of the separator shall be such that air leaving the cyclonic chamber shall be directed upward through a filter bag(s) to effect final cleaning of the air before its entry into the turboexhauster. The lower part of the separator enclosure shall contain an easily accessible and serviceable debris container. The container shall lock into operating position to form a positive seal between the removable container and the separator enclosure, to prevent leakage of the vacuum system. The debris container shall be removable and reinstallable without use of tools. The container shall be equipped with casters to facilitate moving for emptying and reinstallation alignment, and shall have a pivoting handle to facilitate handling. The separator shall be equipped with a filter-shaker mechanism actuated by an electric motor operating through mechanical linkage to the shaker mechanism. An electrical switch to control the shaker motor shall be on or adjacent to the separator and shall conform to appropriate electrical code. The separator shall be equipped with an easily removed, screw- or bolt-fastened access panel to provide easy access for filter inspection and service.

Piping--All EJVS piping shall be sized in accordance with the system manufacturer's recommendations. Pipes shall be of corrosion-resistant material with a smooth internal surface and shall not collapse when installed in an evacuation system evacuated to 8-inHg gauge. Pipes shall be cut square, with burs and flashing removed, and installed with minimum obstruction to airflow. ABS and PVC piping shall conform to Schedule 40 or Class 200 specifications. Fittings, supports, and joint assembly shall be of approved type. The assembled piping system shall be suitable to support 8-inHg vacuum gauge requirement. All fittings shall be of DWV long-radius type. Coupling, union, and other disconnecting fittings shall be readily accessible at all times. Layout and installation drawings, with technical data to assure piping system suitability, shall be submitted to the contracting officer for approval.

Vacuum Inlets--User inlets shall be wall-mounted not more than 24 nor less than 12 inches from inlet center to finished floor top and shall project no more than 0.5 inch from the wall. The inlet shall be of heavy-duty construction with heavy-gauge stainless-steel valve body and door assembly. The external surfaces shall be a satin finish, with all edges and corners beveled so as not to produce a safety hazard. The cover door shall be self-closing and shall have a neoprene or similar gasket on its inner surface that will provide a vacuum-tight seal when closed. The valve shall be sized to 1.5-inch ID and shall receive a 1.5-inch-OD commercial hose cuff with sufficient accuracy of fit to prevent vacuum leakage.

Mobile Wet-Pickup Caddy--The wet-pickup caddy shall be a cylindrical tank of 12-gallon minimum capacity, mounted horizontally on wheels. The tank shall be constructed of 10-gauge minimum-thickness steel with welded joints. Nominal tank dimensions shall be 12 inches diameter and 27 inches long. The tank shall be designed with convex ends to prevent collapse under vacuum. A 14-inch nominal-length axle shall be attached under one end of, and perpendicular to, the long axis of the tank and shall be equipped with 7-inch nominal-diameter wheels. The opposite end of the tank shall have a support leg or caster-set under it to stabilize the tank in a horizontal position while in use, and a push-handle on the top for easy mobility. The top of the tank shall be equipped with inlet and outlet ports. The inlet port shall be a swiveling, removable 90° elbow, sized and equipped to receive a 1.5-inch-ID commercial vacuum hose cuff. The outlet port shall be a fixed 90° elbow attached to an automatic-float-valve assembly sized and equipped to receive a 1.5-inch-ID commercial hose cuff. One end of the tank shall have a drain hole at the lower edge, equipped with an expansion plug with safety chain to prevent loss. The manufacturer shall provide a jumper hose with each wet caddy, to connect the caddy to the wall vacuum inlets. The jumper hose shall be 5-foot nominal length, 1.5-inch ID, and cuffed at each end for proper connections.

Accessories--All hoses for the central vacuum system shall be 1.5-inch-ID commercial-grade corregated vacuum hose, fabricated of PVC or polyurethane, and without wire reinforcement. All hose ends shall be equipped with vacuum hose cuffs compatible with wall vacuum inlets, wet-caddy inlet and outlet, and vacuum tools. Tools shall include a 5-foot S wand of aluminum construction; a master shoeholder with carpet, nylon floor-brush, and squeegie shoes; and a 12-inch-long steel crevice tool.

DESIGN GUIDANCE

High-Volume Oral Evacuation System (HVE) for Dental Treatment Rooms

General Information--The central HVE system is indispensable when the ultra-efficient high-speed air turbine dental handpiece is used and for practically all other procedures in the practice of modern dentistry. Performance and reliability of the HVE system is paramount. This system is designed to rapidly remove air/water spray mist, tooth and amalgam debris, and saliva and water from the mouth of a patient during dental treatment procedures, without damage to oral tissues. All DTRs in the facility design shall have access to the HVE system.

Composition of the System--A central HVE system shall consist primarily of the following:

a. Two turboexhauster units connected in parallel, with individual high- and low-voltage switching controls.

b. Mechanical antisurge devices, directional flow valves, intake controls, and silencers for the turboexhausters.

c. A central air/water separator system located adjacent to the turboexhausters.

d. Mechanical overflow protection; adjustable solid-state liquid-level sensors with shutoff solenoid for vacuum; an automatic, time-adjustable internal washdown system for the central separator(s); and a 40-mesh stainless-steel filter screen for the cold-water supply to the washdown system, to prevent solenoid seat damage.

e. A properly sized piping system to provide two HVE inlets for each DTR.

f. A low-voltage source and panel for remote control and monitoring of turboexhauster performance.

Design Criteria--The HVE system shall develop and maintain a vacuum of 8-inHg gauge at a minimum airflow of 15 SCFM at each DTR input-nozzle orifice. Inside diameter of the orifice is standard at 0.395 inch (10 mm). The nozzle is located at the end of a nominal 0.395-inch-ID hose with a minimum length of 5 feet. Performance shall be maintained regardless of the number of nozzles open. Equipment shall be selected to compensate for elevation of the proposed installation so that performance requirements will be satisfied at job site. Total minimum airflow of the system shall be calculated as the product of the total number of DTRs served and 15 SCFM. The calculated value shall be used to select turboexhauster size from the following standard chart:

Horsepower	SCFM at 8-inHg
7.5	165
10	220
15	350
20	475
25	600
30	725
40	1000
50	1250
60	1550

Ratings are based on air at standard conditions (70°F and 14.7 psia).

The HVE system shall have two turboexhausters, each sized to handle 100% of the calculated load. Exhauster inputs shall be connected in parallel. Each input shall be equipped with a mechanical antisurge valve for vacuum control. The equipment manufacturer shall furnish documented certification of each turboexhauster as to its ability to handle the design loads without exceeding the normal operational limits of the exhauster or drive motor. Ingestion gates and antisurge valves shall be preset to maintain specified design requirements for airflow and vacuum levels. The HVE system shall incorporate one or several central separators as determined by the following criteria:

No. of DTRs	Separator tanks	
	Quantity	Size (gal.)
1-6	1	20
7-10	1	40
11-20	1	80
21-30	2	40
31 and above	2	80

When multiple separators are used, tank inputs and tank exhausts shall be connected in parallel, and liquid-level sensors shall be set to effect drainage at a different level for each tank so that evacuator service to the facility shall not be interrupted.

High-Vacuum Oral Evacuation System (HIVAC) for Oral Surgery, Periodontics, and Endodontics Treatment Rooms

General Information--The HIVAC system produces higher vacuum power (inHg) at a much reduced volume (CFM) than the HVE system. The HIVAC system is designed for use with small-orifice surgical aspirator tips (0.062-inch ID) compared to the larger tips (0.5-inch ID) of the HVE. These smaller tips, operating at 15-20 inHg and 1-2 CFM, are required for safe removal of fluids, sutures, and hard- and soft-tissue debris without damage to viable tissues and without dislodgement of freshly formed blood clots during surgical procedures. The HIVAC function shall be furnished, in addition to the HVE, to all DTRs designated for oral surgery, periodontics, and endodontics and to DTRs dedicated to support General Dentistry Resident Programs in training facilities. The system shall be of essentially dry configuration, with regulators, transparent separators, and overflow protectors at each DTR input.

Composition of the System--The HIVAC system shall consist primarily of the following:

a. A pair of dual-rotor water-ring (water-injected/water-seal) pumps in parallel, with high- and low-voltage switching controls.

b. A vacuum vessel (tank) equipped with vacuum sensors and associated switches for maintaining vacuum within the tank at between 15 and 20 inHg. The tank shall be corrosion resistant and equipped with a manual drain and other plumbing and devices written or implied in the specification.

c. Silencer (muffler) for the common exhaust line of the pumps.

d. Duplex magnetic starter with alternating feature.

e. Low-voltage source and control panel for remote control, with performance indicators for the system.

f. Each DTR inlet shall terminate with a wall-mounted quick-connect/disconnect fitting and be provided with a mating fitting carrying an adjustable vacuum regulator; a transparent separator container with float (minimum 2 liters); an overflow protection device (foamproof); a suction-hose input barb; a suction hose (minimum 5-foot length); three aspirating tips with 0.125-inch (3.18 mm) ID; and three aspirating tips with 0.062-inch (1.6 mm) ID.

Design Criteria--The HIVAC pumps shall individually produce and maintain a vacuum range of 15-20 inHg in the reservoir. Vacuum sensors and switches on the reservoir shall activate the duplex automatic alternating magnetic starter to start up the pump at 15-inHg vacuum level in the reservoir and shut down the pump at 20-inHg vacuum level. Each inlet regulator shall be capable of regulating air volume, at a range of 1-3 CFM, through a 0.125-inch-ID (3.18 mm) surgical aspirator tip. Pumps shall be installed in pairs, with individual pump capacity sufficient to produce the above-specified vacuum (inHg) and airflow (CFM), based on a 60% use factor for the entire system. Pumps shall be sized according to the following as minimum requirements:

No. of DTRs	Single pump HP
1-6	1
7-12	2
13-20	3
21-36	5
37-60	7.5

High-Volume Evacuation System for
Base Dental Laboratories (HVEL)

General Information--The HVEL system scavenges and centrally separates, filters, and collects material trimmings, grinding debris (toxic and nontoxic), and particulates from polishing and finishing operations in the dental laboratory. All air-abrasive, cutting, grinding, and finishing equipment, both portable and stationary, shall have input to the system. Airflow volume shall be sufficient to scavenge these devices to prevent contamination of the laboratory environment. The HVEL system shall exhaust to the atmosphere outside of the laboratory building.

Composition of the System--The HVEL system shall consist primarily of the following:

a. One turboexhauster complete with high- and low-voltage switching controls, a preset field-adjustable ingestion valve, and exhaust silencer.

b. A central cyclonic separator with a filter-bag system.

c. A low-voltage source and remote control panel for remote control and indication of turboexhauster performance.

d. A properly sized piping system to provide one HVEL inlet per technician and other inlets as indicated for equipment specified in the laboratory design.

e. A mechanically operating air volume relief valve, sensitive to negative air pressure to regulate inlet flow rate and equipped with a silencer.

Design Criteria--The HVEL system shall develop and maintain a vacuum of 3-inHg gauge. Total calculated airflow load (SCFM) shall be the sum of 60 SCFM per technician and 150 SCFM for each unit of equipment specified. The system's capacity shall be sized according to the total calculated load modified by one of the appropriate use factors given below:

Laboratory size (No. of technicians)	Use factor (%)
1-4	60
5-10	70
11-15	80
16-24	85

The modified airflow-load value (SCFM) shall be used to select the turboexhauster from the following standard chart:

Exhauster (HP)	Airflow (SCFM)	Motor/Exhauster (rpm)
3	400	1725/2600
5	700	1725/2600
7.5	1100	1725/2600
10	1600	1725/2600
15	2200	1725/2600

User inlets for technicians' benches and at equipment locations shall be positioned on the face of the casework service ledge. Piping shall be routed in the service ledge from designated inlets to the main trunk line and central separator. The trunk line shall be extended outside of the facility, with the air volume relief valve ingesting outside air. Capacity of the central separator shall be based on the following filter-area requirements:

Laboratory size (No. of technicians)	Filter-separator (ft^2)	Primary separator
1-4	60	not required
5-10	100	not required
11-15	300	not required
16-24	300	one required

The primary separator required for larger laboratory design shall also be used in any design, regardless of size, when the specified equipment includes a sand-blasting unit without built-in filtration. This additional protection is required to prevent damage to the vacuum producer. Sand blasters with built-in filtration may be connected to the central vacuum system without a primary separator: This does not preclude the requirement for a primary separator for large laboratories (16-24 technicians). Micro finishing air-abrasive devices using particle sizes of 50-μm diameter and below and shell blasters without built-in filtration are exempt from the primary separator requirement.

Environmental-Janitorial Vacuum System (EJVS)

General Information--The EJVS shall provide for safe and effective janitorial vacuum cleaning throughout the dental facility as well as pickup and trapping of accidental mercury spills, thus controlling mercury-vapor contamination in the staff and patient environment. The system shall also protect user personnel from accidental mercury-vapor exposure as they clean in areas where mercury may collect.

Composition of the System--A central vacuum system shall consist primarily of the following:

a. A vacuum source (HVE turboexhauster(s)).

b. A central dry cyclonic separator with filter bag(s).

c. A properly sized piping system with vacuum inlets at specified locations.

d. Hose(s) and tools for janitorial service.

e. Portable wet caddy(s) with hoses and accessory tools for wet or dry cleaning of mercury spills from smooth floor coverings.

Design Criteria--The EJVS shall be powered by the clinic's HVE turboexhauster system. A vacuum branch line shall be taken off the parallel manifold between exhausters and central wet separator(s). This vacuum branch shall power a central dry separator located adjacent to the wet separator(s). Size capacities for the central dry separator shall be determined by the number of vacuum inlets used at one time (users). Maximum allowable users shall be calculated by the product of total airflow capacity available from the HVE vacuum: product (No. of DTRs x 15 SCFM + 10% for friction loss) divided by 85 SCFM for each user. Separator capacities shall be selected from the following criteria:

No. of users at one time	Separator capacities	
	Dirt can (ft^3)	Filter area (ft^2)
1-3	2.5	30
4-6	3.75	60
7-9	4.5	90
10 and above	4.5	142

To prevent bleeddown of the vacuum source by more users than designed for, the number of vacuum hoses and caddy/hose combinations supplied shall be limited to the calculated number of users. For each user, the vacuum-system manufacturer shall supply a 35-foot-nominal-length, 1.5-inch-ID vacuum hose, cuffed at each end for connection (for attachment of cleaning tools to inlets and to wet caddy). As stated in the SPECIFICATIONS section, each wet caddy shall be supplied with a 5-foot length of jumper hose to connect the caddy outlet to the wall vacuum inlet. The number of wet caddies supplied by the vacuum system manufacturer shall be determined from the following:

No. of users at one time	Wet caddies supplied
1-6	1
7 and above	2

Locations of wall vacuum inlets shall be determined by a 35-foot working radius from each inlet (not straight line) such that all points within the facility are accessible for cleaning.

ACCEPTANCE TESTING

Testing the High-Volume Oral Evacuation System (HVE) for Dental Treatment Rooms

General--Tests shall be performed by the contractor under the supervision of a competent engineer who has had at least 2 years' experience in installing and testing central high-volume evacuation systems for dental operatories. An approved representative of the evacuation equipment manufacturer shall be present during initial system startup and testing. The contractor shall prepare and submit a test schedule and a testing procedure to the contracting officer for approval. The contractor shall furnish all test materials, piping or tubing, equipment, and instruments and shall have all testing instruments calibrated by a qualified independent laboratory. A representative of the contracting officer shall witness all tests.

Pipe Leakage Tests--The completed piping system between the turboexhauster and DTRs shall be exhausted to a vacuum of not less than 8-inHg gauge after the pipe line is dried out initially. The vacuum indicated shall not decrease by more than 0.4-inHg gauge in 1 hour. If the vacuum does not hold, leaks shall be located and repaired; testing will be redone until vacuum holds.

Air Volume and Vacuum Tests--Tests shall be performed to confirm that the system will meet air volume and vacuum requirements at aspirator tips and that turboexhausters will produce the total capacity required. Testing shall be done after all equipment is properly installed and piping is cleaned and proved tight. A nominal 0.395-inch-ID hose of 5-foot minimum length shall be installed at one of the two vacuum hose connections in each DTR. Hoses shall be suitable for maximum system vacuum. Each hose shall handle a minimum air volume of 15 SCFM at a minimum vacuum of 8-inHg gauge without collapsing.

With all DTR hoses fully closed, the first turboexhauster shall be started. Fifteen minutes after startup, the current draw of the turboexhauster drive motor shall be measured with an appropriate amp meter and recorded with the reading of the remote-panel vacuum gauge. All DTR hoses shall then be fully opened and the current and vacuum values again recorded. The first turboexhauster shall then be shut down and the test repeated with the second turboexhauster on-line. To meet partial contract requirements, the electrical power measurements shall not exceed the normal power rating, beyond the fractional rating, of the drive motor, and the vacuum readings shall at all times be maintained at 8-inHg gauge, ± 0.2.

Recorded Test Data--Three copies of recorded test data shall be furnished to the contracting officer.

General Operating Test--A general operating test shall be conducted during or after air volume and vacuum tests to assure that the exhausters start up properly. In addition, each DTR input shall be tested with at least 1 quart of water to assure proper function of individual inputs. Sufficient additional water shall be ingested into the system to demonstrate the successful operation of mechanical overfill protection, the liquid-level sensor/drainage system, and the automatic internal washdown system.

Testing the High-Vacuum Oral Evacuation System (HIVAC) for Oral Surgery, Periodontics, and Endodontics Treatment Rooms

General--Tests shall be performed by the contractor under the supervision of a competent engineer who has had at least 2 years' experience in installing and testing high-vacuum evacuation systems for dental facilities. An approved representative of the evacuation-equipment manufacturer shall be present during initial system startup and testing. The contractor shall prepare and submit a testing schedule and a testing procedure to the contracting officer for approval. The contractor shall furnish all necessary materials, equipment, and instruments and shall have all testing instruments calibrated by a qualified independent laboratory. A representative of the contracting officer shall witness all tests.

Pipe Leakage Tests--The completed piping system between the high-vacuum pumps and the DTR hose connections shall be exhausted to a vacuum of not less than 20-inHg gauge after the pipe line is dried out initially. The vacuum indicated shall not decrease by more than 0.4-inHg gauge in 1 hour. If the vacuum does not hold, leaks shall be located and repaired; testing shall be redone until vacuum holds.

Vacuum Tests--Tests shall be performed to confirm that the system will meet vacuum requirements at the surgical evacuator tip and that the high-vacuum pumps are operating per design requirements. A nominal 0.395-inch-ID hose of 5-foot minimum length shall be installed at each DTR high-vacuum hose connection. Hoses shall be suitable for maximum system vacuum of 20-inHg gauge and airflow of 3 SCFM. Each hose shall be equipped at the nozzle end with a surgical tip (or facsimile thereof) with a nominal 0.125-inch ID. Each pump shall be tested separately. Testing shall begin after all equipment is properly installed, piping cleaned and proved tight, and the system inspected by the manufacturer's representative. The system shall be run for 20 minutes with one pump of the pair operating, 60% of the DTR inlets on-line equipped with test bases and nozzles as described, and the end regulators set for full vacuum. The individual regulators shall be monitored to verify a minimum of 15-inHg for the test period. The test will be repeated using the second pump of the pair. In addition to the 15-inHg minimum requirement for each pump, the vacuum shall not differ more than 1-inHg between the pumps.

Recorded Test Data--Three copies of recorded test data shall be furnished to the contracting officer.

General Operating Test--A general operating test shall be conducted during or after the vacuum tests to assure that the high-vacuum pumps start up properly. In addition, each DTR input shall be tested with at least 1 pint of water to assure proper function of individual inputs and exhaust drains of the pumps.

Testing the High-Volume Evacuation System for Base Dental Laboratories (HVEL)

General--The contractor shall test the HVEL system under the supervision of a competent engineer who has had at least 2 years' experience in installing and testing high-volume evacuation systems for dental laboratories. An approved representative of the manufacturer of the evacuation equipment shall be present during initial startup and testing. The contractor shall prepare and submit a testing schedule and procedure to the contracting officer for approval. The contractor shall furnish all necessary materials, equipment, and instruments and shall have all testing instruments calibrated by a qualified independent laboratory. A representative of the contracting officer shall witness all tests.

Pipe Leakage Tests--The completed piping system between the turboexhauster and the laboratory inlets shall be exhausted to a vacuum of not less than 40.8-inH_2O gauge ± 2.0 after initial drying out of the pipe line. The vacuum indicated shall not decrease by more than 5.4-inH_2O gauge in 1 hour. If the vacuum does not hold, leaks shall be located and repaired; testing will be repeated until the vacuum holds.

Air Volume and Vacuum Tests--Tests shall be performed to confirm that the system will produce and maintain required vacuum at the laboratory inlets; that the turboexhauster is operating per design specifications; and that the system, when operating with any number of inlets on-line within the design limit, is not producing hazardous noise levels. After all equipment is properly installed and piping is cleaned and proved tight, testing shall proceed. After an initial exhauster run of 15 minutes, a sufficient number of laboratory-equipment and technician-bench inlets shall be opened to develop the design airflow load. The current draw of the exhauster drive motor shall be measured with an appropriate calibrated amp meter and recorded with the reading of the remote-panel vacuum gauge. To meet partial contract requirements, the electrical power measurements shall not exceed the normal power rating, beyond the fractional rating, of the drive motor, and the vacuum readings shall at all times be maintained at 40.8-inH_2O, ± 2.0. Next, all inlets in the system shall be fully opened and the drive-motor current draw again recorded. The ingestion-gate adjustment shall be such that at maximum airflow load, the electrical power shall not exceed the motor design limits. Vacuum power (inH_2O), however, should be expected to fall considerably due to bleed-down of the system; this is acceptable. Finally, a noise-measuring instrument shall be used to measure high-velocity-air noise 24 inches from the vacuum inlet orifice. Noise shall not exceed current USAF Occupational and Environmental Health Laboratory (OEHL) limits as calculated on a time-weighted average (TWA) for an 8-hour work day.

Recorded Test Data--Three copies of recorded test data shall be furnished to the contracting officer.

General Operating Test--A general operating test shall be conducted during or after airflow and vacuum tests to assure that (a) the turboexhauster starts up properly and (b) in the opinion of the inspecting engineer, vibration is not excessive and neither belt nor exhaust-air noise exceeds specification limits.

Testing the Environmental-Janitorial Vacuum System (EJVS)

General--The contractor shall perform tests under the supervision of a competent engineer who has had at least 2 years' experience in installing and testing central vacuum systems for health facilities. The contractor shall prepare and submit a testing schedule and procedure to the contracting officer for approval. The contractor shall furnish all necessary materials, equipment, and instruments and shall have all testing instruments calibrated by a qualified independent laboratory. A representative of the contracting officer shall witness all tests.

Pipe Leakage Tests--Piping and inlets of the central vacuum system shall be considered a continuing part of the HVE system and shall be leak tested with the HVE piping.

Air Volume and Vacuum Tests--Air volume and vacuum shall be tested as for the HVE. Testing shall be done with hoses and/or caddy/hose combinations connected to vacuum inlets and with all DTR oral evacuation hoses fully closed. Each vacuum hose shall have a cleaning tool attached while testing. Turboexhauster motor current readings shall not exceed the power rating of the drive motor, beyond the fractional limit. The vacuum power shall not be less than 7-inHg gauge.

Operating and Maintenance Instructions Required for All Systems

Bound Instructions--Six complete sets of the manufacturer's operating and maintenance instructions for each piece of equipment shall be furnished the contracting officer. Each set shall be permanently bound within a hard cover. One complete set shall be furnished at the time the test procedure is submitted; remaining sets shall be furnished before the contract is completed. The following identification shall be inscribed on the covers: OPERATING AND MAINTENANCE INSTRUCTIONS, with name and location of building, name of contractor, and contract number. Fly sheets indexing specific items shall be placed before each section of instructions. The instruction sheets shall be approximately 8.5x11 inches, with large drawings included as foldouts. Instructions shall include, but not be limited to, the following:

System layout showing piping, valves, and controls.

Approved wiring and control diagrams.

A control sequence describing startup, operation, and shutdown.

Operating and maintenance instructions for each piece of equipment, including lubrication instructions.

Manufacturer's bulletins, cuts, and descriptive data.

Parts lists and recommended spare parts.

Diagrams and Operating Instructions--Approved wiring and control diagrams showing the complete layout of the entire system (including equipment, piping valves, and control sequence)--framed under glass or in approved laminated plastic--shall be posted where directed. In addition, operating instructions explaining preventive maintenance procedures, methods of checking the system for normal safe operation, and procedures for safely starting and stopping the system shall be prepared in typed form, framed as specified for the wiring and control diagrams, and posted beside the diagrams. Proposed diagrams, instructions, and other sheets shall be submitted to the U.S. Army Corps of Engineers for approval prior to posting. The framed instructions shall be posted before the systems are tested for acceptance.

Field Instructions--Upon completion of the work and at a time designated by the contracting officer, the contractor shall supply the services of one or more competent engineers for at least 1 day to instruct a Government representative in the operation and maintenance of all central evacuation systems. These field instructions shall cover all items contained in the bound instructions.

UTILITY REQUIREMENTS

High-Volume Oral Evacuation System (HVE) for Dental Treatment Rooms

Electrical Requirements

Turboexhausters--For each turboexhauster provide either a 208-, 230-, or 460-V 3-phase, 60-Hz separate circuit, and terminate at each turboexhauster location. Circuit and wire size are determined by horsepower and amperage. If not ordered with the turboexhausters, install one electrical control panel containing a combination magnetic starter with fused disconnect for each turboexhauster.

Horsepower	Voltage	Amps
7.5	208 V, 3 Φ	19
7.5	230 V, 3 Φ	18
7.5	460 V, 3 Φ	9
10	208 V, 3 Φ	27
10	230 V, 3 Φ	26
10	460 V, 3 Φ	13
15	208 V, 3 Φ	38
15	230 V, 3 Φ	37
15	406 V, 3 Φ	19
20	208 V, 3 Φ	53
20	230 V, 3 Φ	52
20	406 V, 3 Φ	26
25	208 V, 3 Φ	63
25	230 V, 3 Φ	62
25	406 V, 3 Φ	31
30	208 V, 3 Φ	74
30	230 V, 3 Φ	73
30	406 V, 3 Φ	37

Turboexhausters' Remote Control Panel--Install a remote control panel--complete with vacuum gauge, dual 120-V on-off switches, and indicator lights--in dental clinic area for remote control of the turboexhausters. From remote control panel location, run six #14 color-coded wires to turboexhauster electrical control panel. Run three wires from switch 1 to turboexhauster 1 and three wires from switch 2 to turboexhauster 2. Hook up control wires to coil of magnetic starter for each turboexhauster.

Autoflush--For autoflush assembly provide a 115-V electrical outlet on a separate 15- or 20-A circuit. Autoflush timeclock should be set to come on at 0100 and shut off at 0200. Recheck time setting once a week to be sure timeclock is set properly. Always reset timeclock after a power failure or if circuit has been shut off. Flushing must not take place when turboexhausters are in operation.

Water Requirements

Liquid Separator--The separator tank requires a floor sink 12x12x6 inches deep. The sink should discharge through a minimum 3-inch-diameter drain to the sanitary sewer, not to a storm drain. The tank drain can be plumbed to an existing floor sink if necessary; however, in new construction or retrofit projects, a floor sink under or near the tank is good practice. Because of obvious complications should pump failure occur, in-line or sump pumps should be used only as a last resort for the removal of drained effluent.

Autoflush for Liquid Separator--At autoflush location provide a 0.5-inch cold water line, fitted with a 0.5-inch FPT gate valve, for connection to a solenoid valve and 40-mesh filter on the autoflush.

High-Vacuum Oral Evacuation System (HIVAC) for Oral Surgery, Periodontics, and Endodontics Treatment Rooms

Electrical Requirements--Power must be provided for each pump. Circuit size may be determined from the following:

Horsepower (each pump)	Voltage	Amps
1 - 2	110 V, 1 Φ	14
	220 V, 1 Φ	7
	208 V, 3 Φ	12
	230 V, 3 Φ	12
	460 V, 3 Φ	6
3	208 V, 3 Φ	8.8
	230 V, 3 Φ	8.8
	460 V, 3 Φ	4.4
5	208 V, 3 Φ	13
	230 V, 3 Φ	13
	460 V, 3 Φ	7
7.5	208 V, 3 Φ	20
	230 V, 3 Φ	20
	460 V, 3 Φ	10

A separate 110-VAC, 15-A circuit must be available at the location of the electrical control panel to power the low-voltage power supply for the remote control circuit.

Water Requirements--A 0.75-inch cold water supply line with a 0.75-inch manual gate valve is required at the pump/reservoir location to provide seal water for the pumps.

Drain Requirements--A floor sink with minimum dimensions of 12x12x6 inches deep with a 2-inch-minimum-diameter drain to the sanitary sewer is required at or very near the pump/reservoir location. The expulsion of seal water is continuous from each pump while running. The drainage should not contain waste products if the clinical end items are properly used.

Vent Requirements--The exhausted mixture of air and seal water from the pumps passes through a separator immediately after leaving the pump outlet. A 3-inch-minimum-diameter plumbing vent stack is required at the pump/reservoir location to vent separated air to atmosphere outside the facility.

High-Volume Evacuation System for Base Dental Laboratories (HVEL)

Electrical Requirement: Turboexhauster (Belt Drive)--For turboexhausters provide a 208/230/460-V, 3-phase, 60-Hz separate circuit, and terminate at the turboexhauster location. Circuit and wire size are determined by horsepower and amperage. If electrical control panel is not furnished with turboexhauster, install a combination magnetic starter with fused disconnect with the turboexhauster.

Horsepower	Voltage	Amps
3	208 V, 3 Φ	9
3	230 V, 3 Φ	9
3	406 V, 3 Φ	4.5
5	208 V, 3 Φ	13
5	230 V, 3 Φ	13
5	406 V, 3 Φ	12.5
7.5	208 V, 3 Φ	20.2
7.5	230 V, 3 Φ	20.2
7.5	460 V, 3 Φ	10.1
10	208 V, 3 Φ	26
10	230 V, 3 Φ	26
10	460 V, 3 Φ	13
15	208 V, 3 Φ	38
15	230 V, 3 Φ	37
15	406 V, 3 Φ	19
20	208 V, 3 Φ	48
20	230 V, 3 Φ	48
20	406 V, 3 Φ	24

Electrical Requirement: Turboexhauster Remote Control Panel--In dental clinic area, install a remote control panel--complete with vacuum gauge, single 24-V on-off switch, and indicator light--for remote control of the turboexhauster. From the remote control panel location, run (a) three #14 color-coded wires to the turboexhauster electrical control panel, and (b) a 0.25-inch flexible polyethylene line to the nearest vacuum line.

Electrical Requirement: Filter-Bag Shaker--At central filter-separator location, provide a 115-V electrical outlet for motorized filter-bag shaker.

Environmental-Janitorial Vacuum System (EJVS)

Electrical Requirements

Turboexhauster--None

Filter-Bag Shaker--This requirement is identical to that for the laboratory (HVEL) filter-shaker.

Waste Requirements: None

Water Requirements: None

GLOSSARY

ABS	Acrylonitrile butyl styrene.
CFM	Cubic feet per minute (0.028 m^3/min); used as the unit of volume of air delivered (airflow).
Dripproof	An electric motor with a housing so designed that dripping liquids cannot enter the housing to affect performance.
DWV	Drain, waste, and vent.
FPM	Feet per minute (0.3048 m/min); the unit of velocity of air movement, which describes the speed of a molecule of air in the mass of moving air.
FPT	Female pipe thread.
GRP	Glass-reinforced plastic.
inHg	Inches of mercury; the unit of vacuum pressure which represents the negative pressure required to lift a column of mercury 1 inch (2.54 cm) in the containing glass tube (1 inHg = 13.6 inH_2O).
MPT	Male pipe thread.
NEMA	National Electrical Manufacturers Association. Electric motors that carry the NEMA frame designation are constructed to meet dimensional standards set by the industry.
PVC	Polyvinyl chloride.
rpm	Revolutions per minute; the unit of rotary speed for spinning bodies.
SCFM	Standard cubic feet per minute (at standard air conditions of 14.7 psia and 70°F, or 21°C).
Stub	The outer end of a central pipe network.
T-frame	A totally enclosed electric motor housing to protect against dust, dirt, and dampness.
VAC	Volts alternating current. For CONUS installations, the frequency of alternating current is 60 Hz. Out-of-CONUS installations may require 50-Hz equipment.

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